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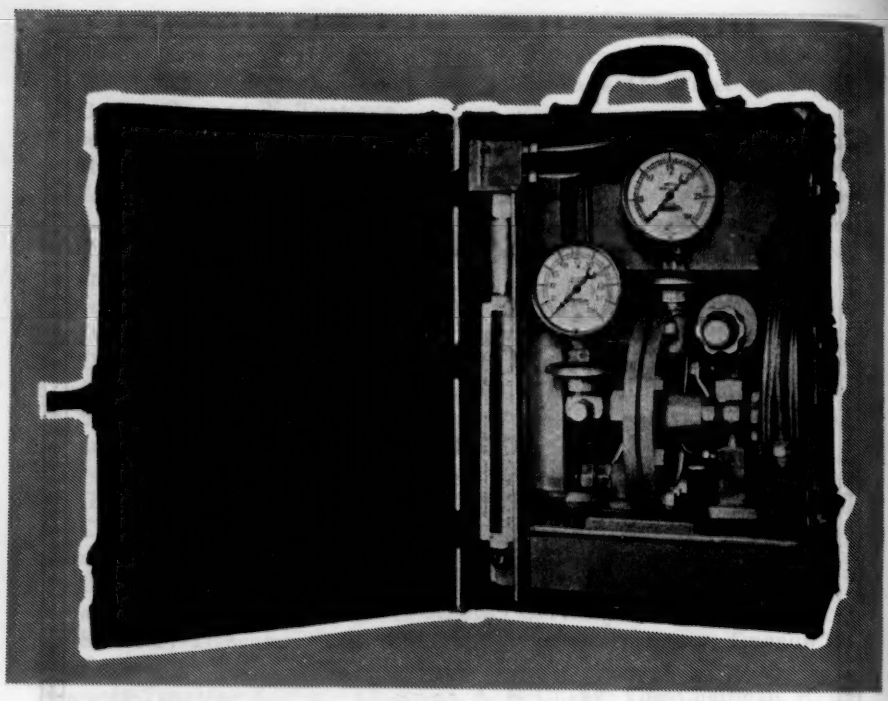

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THE TRIAL FILTRATION PLANT, OTTAWA, CANADA[1]

BY GEORGE G. NASMITH[2]

The citizens of Ottawa, the capital city of Canada, in December, 1928, by an overwhelming majority voted to build a filtration plant to treat the Ottawa river water used as the civic water supply. Upon the advice of the commissioner of works, the water works engineer of Ottawa and the consulting engineers of the City Council decided that first a trial filter should be built and operated to obtain as complete information as possible about the water supply and its amenability to treatment at all seasons and under all climatic conditions.

An appropriation of $10,000 was voted for the purpose and the consulting engineers designed a trial filter which had a total capacity of 96,000 Imperial gallons per day. This plant, constructed under the direct supervision of the Works Department of the City of Ottawa, consisted of two independent concrete filter units each including a mixing chamber, settling tank, filter and necessary pumps, control apparatus, chemical administration equipment and other essential features. Each complete unit was designed to treat 48,000 Imperial gallons per day at the rate of 105 million Imperial gallons per acre per day. A laboratory formed an essential part of the trial plant. After

[1] Presented before the Water Purification Division, the St. Louis Convention, June 5, 1930.

[2] Of Gore, Nasmith and Storrie, Consulting Engineers, Toronto, Ontario, Canada.

tuning up so that each filter ran exactly the same as the other the method of operation was to make a single change in some feature of the treatment or method of operation in one unit and compare the result obtained with that from the other which was always kept operating as a control.

In the experimental plant several devices were found to be of inestimable value. The first was a portable electric reflector capable of throwing a beam of light into the water in the tanks in order to see just what condition the floc was in, how it was settling and what currents were being set up. The second was the pH determination for accurately checking the process in all its stages. The third was the use of a rapid colorimetric test worked out by the writer for determining the amount of floc present at any step in the process. In addition to these three devices which were in constant use we found the use of 500 cc. glass graduates for measuring the amount of floc which settled out and a 9-foot glass cylinder for taking core samples to be of great value in determining the distribution and quantity of floc settling in the sedimentation tanks.

As a result of our work some new features are being incorporated in the main plant now being designed and when it goes into operation the operators will have a thorough knowledge of the peculiarities of the river water, its treatment and the difficulties likely to be encountered, and because of their training with the trial filters will be able to meet and readily overcome them.

The results obtained naturally fall into two parts, those obtained in the laboratory including all the bench experiments and those obtained on the trial filters themselves. As far as has been possible the two have been segregated so that the first part of the paper deals largely with the bench experiments and the second part with the results obtained from the large experimental plant.

PROCESS OF FLOC FORMATION

Floc formation involves two visible processes. The first is the appearance of insoluble aluminium hydrate as a result of the chemical reaction which occurs between the aluminium sulphate and the alkaline salts in the water, a reaction which occurs in the Ottawa River water very rapidly and is indicated by the cloudiness which immediately appears in the treated water. No detrimental effect to this reaction in the Ottawa river water was produced by adding the alum before the water passed through the pumps or by any other violent

agitation immediately after the alum had been added and before floc formation occurred. The second process is that of the aggregation of this cloudy aluminium hydrate, color and materials thrown out of suspension or solution into comparatively large particles of floc, heavy enough to settle from the quiescent or slowly moving body of water. This Ottawa river floc proved to be exceedingly delicate and was rapidly converted into its original cloudy form by pouring a well flocced sample from one jar into another, roughly stirring it or allowing it to flow rapidly into a body of still water.

Such treatment, however, did not permanently damage the floc. Two quart samples treated with 2, 2½, 2¾, 3, 4 and 5 grains of alum per gallon[3] were stirred for 20 minutes at 60 revolutions per minute and allowed to settle for an hour, then rapidly agitated with a mechanical stirrer to destroy the floc and finally stirred slowly at 60 revolutions per minute for 15 minutes. It was found that rapid stirring for 5, 10, or 15 minutes did not injure the aluminium hydrate more than rapid stirring for one minute. There was no perceptible difference in the process of reforming the floc in the samples treated with the larger than with the smaller doses of alum.

In order to bring about floc formation quickly as a means of measuring experimental results it was necessary to adopt a uniform method of stirring the treated water. In bench experiments a very rapid stirring was usually given the sample after the addition of the alum solution from the burette. Floc formation developed very slowly in treated samples allowed to stand without further stirring, and 24 hours later, even though much of the coagulum had settled out, some cloudiness still persisted in the supernatant fluid due to suspended aluminium hydrate. Upon slowly stirring these 24 hour treated samples the suspended coagulum in a few minutes was converted into well formed particles of floc which rapidly settled out on standing. Satisfactory floc formation did not occur in samples treated with sufficient alum when stirred for less than 15 minutes no matter what the speed of stirring was. Experiments showed that the length of time of stirring was of more importance than the rate, provided that this was not excessive. Satisfactory results were obtained in the laboratory with a Baylis stirring machine at any rate between 40 and 90 revolutions per minute.

Increasing the rate of stirring did not improve the character of the floc or the speed of settling. For example it was found that stirring

[3] Imperial gallon is used throughout this paper.

at 45 revolutions per minute for 25 minutes produced a large floc which rapidly settled out. This was a total of 1,125 revolutions. Experiments were conducted at the rate of 60 revolutions per minute for 18¾ minutes, at 70 revolutions per minute for 16 minutes and at 75 revolutions per minute for 15 minutes, a total in each case of 1,125 revolutions. The sample at 45 revolutions for 25 minutes was the best in the appearance of floc, rapidity of settling and in clarity of the supernatant liquid. Yet when the last two samples were run for 25 minutes at the higher speeds mentioned they settled out just as well as the sample at 45 revolutions for 25 minutes. It was not possible to compensate for the shorter time of mixing by increasing the number of revolutions.

A series of experiments was made in which mixing by compressed air in jars was compared with mechanical mixing. Finely divided air as a means of mixing the treated water and producing a suitable floc did not prove to be as affective as mechanical mixing for the slightest excess of air necessary to produce a good floc dispersed it thoroughly.

EXPERIMENTS WITH PREFORMED FLOC

Laboratory experiments were carried out to determine the effect of adding preformed floc to samples of water treated with alum and given a preliminary rapid stirring and the remainder of the stirring carried out at 60 revolutions a minute for 25 minutes. The samples to which preformed floc had been added were not superior to those to which no preformed floc had been added, nor was there any noticeable improvement in the rate of settling. The addition of preformed floc did not cut down the length of stirring time necessary to bring about complete flocculation. Preformed floc was also added to samples treated with 2½ grains of alum and given a rapid preliminary mix and allowed to stand to see whether the preformed floc would carry down the unformed coagulum. Preformed floc apparently had no value in improving flocculation with this particular dose. It is possible, however, that the addition of preformed floc to any water which had been given small doses of alum would improve the size of the floc and bring about better floc settling and improved length of filter runs even though it did not remove color.

THE USE OF ALUM AS A COAGULANT IN THE LABORATORY

Experimental bench work was carried on to determine the optimum pH range for coagulation with alum.

Flocculation and color removal with alum without adjustment of pH of raw water:

Raw water pH..... 7.2
Alkalinity..... 18
Color..... 70
Temperature..... 21.3°C.

ALUM USED	pH AFTER STIRRING	COLOR	FLOC
g.p.g.			
2½	5.5	0	Excellent
2⅜	5.7	0	Excellent
2¼	5.9	5	Good
2	6.0	20	Poor
1⅞	6.0	50	None
1¾	6.1		None

These results show that without adjustment of the pH of the raw water colorless water can be produced with 2½ g.p.g. and with a slight trace of color with 2¼ g.p.g.

Applying the total alum dose in two parts was also tried on raw water. No more color was removed with the same total dose by splitting up the amounts of alum used.

THE EFFECT OF pH ON FLOCCULATION OF OTTAWA RIVER WATER

In order to determine the optimum condition for flocculating the following series of tests were run:

Raw water pH 7.2

pH BEFORE ALUM	pH AFTER ALUM	COLOR	FLOC
Series 1. Using 2 grains of alum per gallon with the pH of the raw water previously adjusted with sulphuric acid so that a large range of pH values was covered			
7.2	6.1	60	No floc
6.9	5.9	15	Good
6.7	5.7	7	Good
6.5	5.3	5	Good
6.4	4.9	14	Good
5.9	4.7	20	Good

Raw water pH 7.2—*Concluded*

pH BEFORE ALUM	pH AFTER ALUM	COLOR	FLOC
Series 2. Using 1¾ grains of alum per gallon and previously adjusting the pH of the raw water with sulphuric acid			
6.9	5.9	35	Poor
6.7	5.8	14	Good
6.5	*5.5*	*3*	Good
6.3	*5.3*	*3*	Good
5.7	4.6	9	Fair
5.5	4.6	14	Fair
Series 4. Using 1⅞ grains per gallon and pH of raw water previously adjusted			
6.7	5.9		No floc
6.5	5.7		No floc
6.0	*5.2*	*14*	Fair
5.9	*5.0*	*18*	Fair
5.4	4.6		No floc
6.8	5.8		No floc
Series 5. Using 1⅞ grains per gallon over a smaller range than series 4 with pH of raw water previously adjusted			
6.5	5.7		No floc
6.3	5.5	18	Fair
6.1	*5.2*	*14*	Fair
6.2	5.7		No floc
6.0	*5.1*	*15*	Fair
5.8	4.9	18	Fair

By so taking progressively smaller doses and narrowing down the possible limits of floc formation it was possible to find the smallest dose which would give a floc under any conditions of pH. Such a dosage is very sensitive to slight changes in acidity. Visible floc is formed only within very narrow limits of pH, while with slightly higher doses visible floc is produced over a very much larger range, though the best color removal occurs over a small range when the dose is increased. With 2¾ grains per gallon a good floc is formed over a very large pH range and complete color removal also occurs over a comparatively large pH range.

A study of the above tables shows that the range of acidity in which floc is produced best is pH 5.1 to pH 5.4.

When it was found that flocculating with alum could be carried on best

at a pH of 5.1 to 5.4 after the addition of alum a series of tests were made by adding various quantities of alum to raw water so adjusted that the resultant pH lay between 5.1 and 5.4.

By this means the lowest possible dose that would completely remove color could be readily determined. Table 1 shows the safe dose that could be employed whenever the pH of the raw water changed to any extent. The table does not necessarily indicate the minimum dose for each pH to yield color free water, although in the case of smaller doses it does. Thus from the table it is seen that to use a dose of $2\frac{3}{4}$ grains per gallon the raw water should have a pH of 7.1. Yet it is known that $2\frac{3}{4}$ grains of alum would produce color free water at a much higher pH. Consequently if the pH of the raw water

TABLE 1

pH RAW WATER BY ADDING H_2SO_4	DOSE ALUM TO BRING WITHIN OPTIMUM RANGE	pH AFTER ALUM	COLOR
7.1	$2\frac{3}{4}$	5.4	0
7.0	$2\frac{1}{2}$	5.5	0
6.8	$2\frac{3}{8}$	5.5	0
6.7	$2\frac{1}{4}$	5.5	0
6.6	$2\frac{1}{8}$	5.4	0
6.5	2	5.4	0
6.4	$1\frac{7}{8}$	5.1	5
6.3	$1\frac{5}{8}$	5.3	10
6.2	$1\frac{1}{2}$	5.2	15

should be 7.1 the dose necessary to produce color free water could actually be reduced with safety. As the doses become smaller the narrower does this allowable range become and the closer must the pH be kept to 5.1–5.4 to obtain the required color removal. Thus for $2\frac{3}{4}$ grains per gallon of alum we can obtain complete color removal with pH as high as 6.0 but with 2 grains per gallon of alum we must stay within the range 5.1 to 5.4.

GENERAL CONCLUSIONS RE ALUM

1. Table 1 shows that when coagulating with alum within the optimum range (i.e., pH 5.1 to 5.4) 2 grains per gallon is the least quantity that can be used to completely remove color from the Ottawa river water.

2. With proper adjustment a floc can be obtained with as little as $1\frac{3}{8}$ grains per gallon.

3. Without adjustment $2\frac{1}{2}$ grains per gallon of alum give complete color removal.

4. Without adjustment a floc can be obtained with as little as $1\frac{7}{8}$ grains per gallon of alum.

One may be justified in concluding that as there is only $\frac{1}{2}$ grain per gallon of alum difference in the least amount of alum that can be used under these two extremes of pH, i.e., 7.4 and 6.5 a considerable difference of pH may take place in the raw water without materially affecting the alum dose. Preliminary adjustment of the pH of the raw water with acid would not be considered because of public opinion. Adjustment of the pH by the use of alum itself is not as cheap as by acid, but the alum supplies more floc, makes it unnecessary to worry about exact adjustment of the pH and makes the operation much simpler.

It may be stated here that during nearly all of the experimental work on the trial filters $2\frac{3}{4}$ grains per gallon of alum was used. This was large enough to provide a sufficient margin of safety under all conditions, always yield a color free water and make all results obtained comparative.

SODIUM ALUMINATE AND COAGOL

Bench experimental work did not indicate that either of these coagulants, or combinations of them with alum, would be as advantageous as alum alone in the treatment of Ottawa river water.

THE USE OF FERRIC CHLORIDE AS A COAGULANT FOR OTTAWA RIVER WATER

It was possible that iron chloride might prove a suitable coagulant for Ottawa river water and a great deal of laboratory work was done in an effort to find out whether alone or in conjunction with alum it could be used satisfactorily.

Ottawa river water has an average color of 70 to 80, acidity of 3, alkalinity of 18 to 38, total hardness of 45 to 70 and pH of 7.0 to 7.4. The intention is to deliver a water absolutely free from color and non-corrosive so that in all our work with coagulants it was necessary to produce effluents which were color free.

Our early experiments were concerned in combining the iron salt

with alum in an attempt to weight the floc. Mixing the ferric chloride first before adding the alum seemed to give a better and quicker settling floc than when the two coagulants were mixed together beforehand, or added together, or when the alum was added first. A total of $2\frac{1}{4}$ grains per gallon of which $\frac{3}{4}$ grain was ferric chloride seemed to be the smallest total dose capable of producing a satisfactory floc.

The effect upon floccing by a mixture of ferric chloride and alum mixed at 60 revolutions a minute for 25 minutes is shown in table 2.

For a total of $2\frac{1}{2}$ grains per gallon of mixed coagulants a good floc

TABLE 2

Color raw water = 80

GRAINS PER GALLON			SETTLING	COLOR AFTER FILTRATION
$FeCl_3$	Alum	Total		
$\frac{3}{4}$	$1\frac{1}{2}$	$2\frac{1}{4}$	Moderately rapid	8
$\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	Moderately rapid	8
$\frac{1}{4}$	2	$2\frac{1}{4}$	Moderately rapid	5
0	$2\frac{1}{4}$	$2\frac{1}{4}$	Moderately rapid	5

TABLE 3

GRAINS PER GALLON			COLOR AFTER FILTRATION	FLOC
$FeCl_3$	Alum	Total		
$\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{1}{2}$	Less than 5	Best floc
$\frac{1}{2}$	2	$2\frac{1}{2}$	Less than 5	Excellent
$\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	Less than 5	Excellent
$\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{1}{2}$	Less than 5	Excellent
0	$2\frac{1}{2}$	$2\frac{1}{2}$	Less than 5	Excellent

was produced in all samples. There seemed to be some advantage in the first combination of iron and alum over alum alone in rapidity of settling and weight of floc.

About this stage in our experimental bench work a mixture consisting of $\frac{3}{4}$ grain ferric chloride and 2 grains alum per gallon was used in the trial plant itself with disastrous results. The brass orifices and copper floats and other copper connections in the dose regulating apparatus were so corroded in two hours as to be useless and the experiment had to be discontinued.

To determine the least amount of ferric chloride which would give a

floc without adjusting the pH of the raw water, the experiments in table 4 were run.

This was repeated when the raw water had a pH = 7.4, with the results shown in table 5.

With ferric chloride alone and without previous adjustment of river water a satisfactory effluent could not be obtained with less than 3 grains per gallon of ferric chloride whereas with alum alone complete color removal could be obtained with 2½ grains under similar conditions.

TABLE 4

pH raw water = 7.2

$FeCl_3$	pH AFTER	FLOC
g.p.g.		
1	6.62	None
1½	6.00	None
2	5.7	None
3	4.5	Good
4	Below 4.0	None

TABLE 5

$FeCl_3$	pH AFTER	FLOC	COLOR
g.p.g.			
3¾	Below 4.0	Excellent	3
3	4.4	Excellent	4
2¼	5.5	None	
2½	5.2	Very poor	80
2¾	4.7	Excellent	8
3	4.4	Excellent	6

With 3 grains per gallon $FeCl_3$ (raw water pH 7.2) the optimum pH for coagulation with $FeCl_3$ was found to lie between pH 4.0 and 4.7.

With 2½ grains $FeCl_3$ per gallon the optimum pH for coagulation with $FeCl_3$ was found to lie between pH 4.1 and pH 4.8.

With 2 grains $FeCl_3$ per gallon only, the samples with a pH of 4.6 and pH 4.2 gave a floc and the latter was better. Therefore the optimum coagulating point for $FeCl_3$ was very close to pH 4.2.

To see how small a dose of $FeCl_3$ would give a floc at pH 4.2 the following series of experiments was run.

pH before $FeCl_3$.....	6.4	6.0	5.7	5.3	5.3	5.1	5.0	4.7
Dose $FeCl_3$ grains per gallon.....	2	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{8}$	1	$\frac{7}{8}$	$\frac{3}{4}$
pH after $FeCl_3$ and stirring.....	4.4	4.3	4.1	4.0	4.0	4.3	4.2	4.1
Floc.....	Excellent	Good	Good	Good	None	None	None	None

To find the minimum dose of ferric chloride which would produce color removal to less than 5, the water was adjusted so that coagulation took place near pH 4.2 with the pH of raw water at 7.2.

TABLE 6

DOSE	pH BEFORE	pH AFTER	COLOR	DISSOLVED IRON IN FILTRATE
				p.p.m.
$1\frac{1}{4}$	5.5	4.1	55	0.75
$1\frac{3}{4}$	5.8	4.1	30	0.50
2	6.1	4.3	40	0.70
$2\frac{1}{2}$	6.2	4.1	5	Trace
$2\frac{3}{4}$	6.2	4.1	0	Trace
$2\frac{3}{4}$	7.2	4.8	30	Approx. 2

Therefore, $1\frac{1}{4}$ grains per gallon $FeCl_3$ flocced at the optimum point was the smallest dose that would give a floc in Ottawa river water (with alum at its optimum point $1\frac{3}{8}$ grains per gallon was the lowest). For complete color removal, however, under optimum conditions $2\frac{1}{2}$ to $2\frac{3}{4}$ grains of ferric chloride were necessary, whereas with alum, flocculating under its most favorable conditions, zero color could be obtained with as little as 2 grains per gallon. This showed a decided advantage of alum over ferric chloride as a color remover not only in quantity but in cost.

When the color had been reduced to zero in water treated with $2\frac{3}{4}$ grains $FeCl_3$ per gallon there was only a trace of iron left, in fact less than that in the raw water which contained approximately 0.3 p.p.m. When the raw water was treated with $2\frac{3}{4}$ grains $FeCl_3$ per gallon without adjustment the iron in the effluent was more than 2 p.p.m.

With $2\frac{3}{4}$ grains alum per gallon and with no adjustment there was practically no iron in the filtrate.

Alum therefore was indicated in every way as a more suitable coagulant than ferric chloride for Ottawa river water. Alum removes iron from the raw water without previous adjustment whereas ferric chloride, without careful adjustment, was likely to actually increase the iron content of the treated water.

Furthermore if the colorless filtrate from $2\frac{3}{4}$ grains per gallon $FeCl_3$ coagulated at pH 4.1 is treated with alkali to prevent corrosion color again develops, as shown below:

	Color
pH 4.2	0
pH 5.7	trace
pH 6.3	5
pH 6.5	5
pH 6.7	18
pH 7.1	18
Over 8	18

The colorless filtrate from alum coagulated water was similarly tested but in this case color did not develop:

	Color
pH 5.6	0
pH 6.9	0
pH 8.0	0
Over 8.4	0

Therefore, when ferric chloride was used as a coagulant the treated water could not be brought back to a pH higher than 6.7 without becoming colored again. Such water would probably be corrosive.

Many combinations of ferric chloride and alum as coagulants were used in bench experiments and without going into unnecessary details it may be stated that no combination of iron and alum flocced at its best pH, showed any decided advantage over iron which in turn is not as good as alum at its optimum point. Furthermore alum could be used alone with excellent results in Ottawa river water without any adjustment of its pH, whereas when ferric chloride was used the pH had to be adjusted by the addition of acid which would necessitate the addition of more alkali after filtration to avoid corrosion.

We concluded that ferric chloride was inferior to alum as a coagulant for Ottawa river water for the following reasons:

1. With adjustment of the pH of the raw water just as much ferric chloride is required as alum. Ferric chloride is much more expensive.
2. Without adjustment of the pH of the raw water more ferric chloride is required to give a colorless effluent than alum.
3. More lime is required after the use of ferric chloride to render the treated water non corrosive.
4. The effluent from Ottawa river water coagulated with ferric chloride and made non corrosive by the addition of lime develops a high color.
5. Unless the pH of Ottawa river water is very carefully adjusted before coagulation with ferric chloride there would be an excessive quantity of iron in the filtrate which would probably cause red water.

CORROSIVE ACTION OF OTTAWA RIVER WATER

In Ottawa it was generally believed that the water was corrosive. It was apparent that the water after coagulation with alum would be more corrosive and that the increase in acidity would have to be corrected.

Air, bubbled through water treated with $2\frac{3}{4}$ grains per gallon alum, removed the free carbonic acid completely in half an hour and affected the pH as follows:

Initial pH of water treated with $2\frac{3}{4}$ grains alum—5.5

	WITH MECHANICAL STIRRING	WITH AERATION
pH at end of 5 minutes	5.5	5.6
10 minutes	5.5	5.8
15 minutes	5.6	5.9
20 minutes	5.6	6.0
25 minutes	5.7	6.1
30 minutes	5.7	6.1

From this table it may be seen that the initial pH of 5.5 was increased to pH 6.1 in twenty-five minutes.

TREATMENT WITH LIME TO AVOID CORROSION

One grain of lime per gallon increased the total hardness by approximately 10 p.p.m., the alkalinity by approximately 7 p.p.m. and the pH by approximately 1.4.

A dose of 2 grains of lime brought the Ottawa filtered water back just to the saturation point when a dose of $2\frac{3}{4}$ grains per gallon of alum had been used.

COLOR IN TRIAL FILTER EFFLUENT

In bench experiments when an insufficient quantity of alum had been added to a sample of raw water, the treated water properly stirred to obtain a good floc and then filtered the filtrate contained true color. This residual color could be removed by adding the further necessary quantity of alum and filtering.

When however, on the trial filters a sufficient quantity of the alum coagulant had been used to remove color and at the end of the filter run color appeared in the effluent this color was not residual color, but the color in dispersed floc. This could be easily shown by subjecting some of the colored effluent from the filters to fifteen minutes stirring with the Baylis mixing machine and then allowing it to stand. After some time a thin film of colored floc appeared on the bottom of the receptacle and the supernatant fluid was quite free from color. In other words when color appeared in the effluent from the trial filter it was a signal that floc was coming through with other constituents contained in the floc.

LOSS OF HEAD

In ordinary filter practice it is the custom to take a certain loss of head as the end of the filter run. In the Ottawa trial filter the loss of head was so small when color appeared in the filtered water that it was considered advisable to take the appearance of color in the filtered water as the sharpest indication that the filter had ceased to function properly. This was the natural end point for the reason that a colorless water was wanted and color came through with a loss of head varying from 8 to 60 inches. When color once appeared in the effluent it proved to be impossible to increase the loss of head any further. In fact after a few minutes the color of the effluent became as high as that of the applied water showing that the filters were no longer effective.

THE USE OF COLLOIDERS IN THE OTTAWA TRIAL FILTERS

When the Ottawa trial filters were put into operation the filter runs during the early stages were very short, averaging about six

hours on both filters. It was quite obvious to the sight that excessive quantities of floc were being carried right through the sedimentation tanks on to the filters and that much of this floc was so fine as to be practically non-settling.

The trial filters were operated at the standard rate of 105 Imperial gallons per acre per day with $2\frac{3}{4}$ grains of alum per gallon which was sufficient to completely remove color. This being the situation experiments were initiated to determine if possible whether the fine floc could not be aggregated into larger and heavier particles which would settle in the sedimentation tanks, and so by removing the excessive load from the filters prolong the filter runs.

It was thought that the colloider idea might be applied to the problem of aggregating the fine floc suspended in the treated Ottawa river water and it was readily shown that a piece of string, wire or branch suspended in the sedimentation tanks became rapidly coated with a furry layer of floc, and that when this layer grew thick enough it fell off in comparatively large pieces and sank to the bottom.

With this fact in mind light wooden frames that could be easily slipped into place were made of the same cross section as the sedimentation tanks, covered with chicken wire and wedged in position so that the flow had to pass through the wire netting. In a few hours the strands of wire were covered with a heavy gelatinous coating of floc which eventually became heavy enough to separate and sink to the bottom in flakes. As the interstices in the wire mesh were relatively large they permitted most of the floc to pass through without the contained floc particles coming into contact with the wire strands. Minnow netting with a mesh of four to the inch was next used to make colloiders similar to the wire mesh colloiders. After the sizing had been extracted from the thread of the nets these screens also became heavily coated with floc but with the difference that when the threads were well covered the open spaces in the mesh were very small and few particles could pass without coming into contact with the floc on the screens.

Three screens covered with minnow netting were placed in No. 2 sedimentation tank, the first tank being operated as a control. The immediate effect was to increase the filter run in No. 2 filter to 9 hours while filter No. 1 still ran only 6 hours. Jars suspended about 2 feet from the bottom in the same relative positions in both tanks caught much more floc in No. 2 tank than in No. 1.

Three additional screens were then placed in tank No. 2, as before

about 2 feet apart. The filter run in No. 2 increased to 12 hours whereas No. 1 filter still ran along at 6 hours.

Examination of the tank containing the net colloiders and the control showed remarkable differences. The flow of the current seemed to be materially slowed by the nets and evened up over the whole area of the tank. There was much less floc visible on the downstream face of the colloiders and accurate tests extending over months as to the quantity of floc settling in both tanks showed that the colloiders induced greater sedimentation at the inlet end of the tank, while the greatest amount of floc settled at the outlet end of the tank which had no screens. A beam of light penetrated deeper and deeper into the water in the tank fitted with the colloider screens towards the filter end while in No. 1 tank there was little difference. One could see the wash water trough in filter No. 2 but not in No. 1.

It was observed that relatively rapid cross currents flowed along

TABLE 7

Comparative filter runs

RUN NUMBER	HOURS		
	Tank without screens	Tank with 3 screens	Tank with 6 screens
1	$5\frac{1}{4}$	9	$11\frac{3}{4}$
2	$5\frac{3}{4}$	9	$12\frac{3}{4}$
3	$6\frac{3}{4}$	9	$12\frac{1}{4}$

irregularly until they struck the colloiders and then suddenly were stilled as they were forced to spread out over a greater area.

The gelatinous floc which first settled on the meshes gradually enlarged until the whole net was covered with a gelatinous film. This film allowed water to pass but trapped the particles of floc. The mass of floc which formed was gradually squeezed through the mesh, sometimes in the form of worm like threads, which were heavy, broke off and sank. Some fine material of course managed to get by and there seemed to be a certain amount of dispersion of the particles squeezed through. When the colloider was carefully withdrawn a thin sheet of transparent gelatinous film could be seen covering most of the net, and this film could be punctured with a knife blade without rupturing it. When laid in a horizontal position this gelatinous film would allow water containing floc to readily pass through it but retained the floc particles.

Table 8 shows the relative distribution of floc deposited in four jars suspended in each sedimentation tank, the jars being in the same relative positions in each tank and 2 feet from the bottom.

In order to check the results obtained by using the screens three of the six screens were removed from tank No. 2 and placed in tank No. 1. Table 9 shows typical runs on filters No. 1 and 2 together with volumes of floc collected in series of settling jars placed as above.

The three remaining screens in tank No. 2 were then moved to tank No. 1 with the result that the run in tank No. 1 increased to 12 hours and the run in tank No. 2 dropped to 6 hours. These experiments

TABLE 8

Inches accumulation of floc

	INLET END		OUTLET END		TOTAL
	1	2	3	4	
	inches	*inches*	*inches*	*inches*	*inches*
Tank No. 1 without screens.....	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$2\frac{1}{4}$
Tank No. 2 with 6 screens.....	2	$1\frac{3}{8}$	$1\frac{1}{4}$	$\frac{1}{4}$	$5\frac{7}{8}$

TABLE 9

	INLET END		OUTLET END		TOTAL	LENGTH OF RUN
	1 jar	2 jars	3 jars	4 jars		
	inches	*inches*	*inches*	*inches*	*inches*	*hours*
Tank No. 1 with 3 screens	1	1	$\frac{3}{4}$	$\frac{3}{8}$	$3\frac{1}{8}$	$9\frac{1}{4}$ (Gain 3 hours)
Tank No. 2 with 3 screens	1	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{4}$	$2\frac{7}{8}$	$10\frac{1}{2}$ (Loss 3 hours)

showed conclusively that the screens had exerted a very definite effect in increasing the length of run, which within limits depended upon the number of colloider screens.

The experiments with screens were continued for three months and invariably gave the same results. Placing the screens closer together was not beneficial. Neither was there any material gain in length of run by using 9 screens instead of 6.

Tapping the screens knocked all the floc off and the following runs were never any better than those in the filters without screens.

Brush mattresses made up of bundles of compressed brush one foot

thick, 5 feet wide and 9 feet deeper were also made and placed in the tanks as colloiders. As a result the filter runs were lengthened to some extent, but not as much as by the net screens and the experiment was abandoned.

Although the results obtained with screen colloiders did not eventually prove to be of practical application they were the means of enabling us to discover a great deal about the currents which developed in sedimentation tanks and their effect upon floc settling.

FLOC EXPERIENCES ON THE TRIAL FILTERS

During the months from February to June the trial filters operating normally with $2\frac{3}{4}$ grains per gallon of alum gave filter runs of an average of only 6 hours. By the use of colloider screens filter runs were increased to as much as 16 hours and more, but it was realized that the screens were only correcting imperfections which should not have been present and that the fault lay either in stratification in the sedimentation tanks due to variations in temperature or to defective floc formation through inadequate mixing or to destruction of the previously formed floc in its passage through the perforated openings in the walls between the mixing chambers and the sedimentation tank.

Bench experiments had yielded a great deal of information as to the formation of floc under varying conditions and its fragile nature. In the laboratory perfect floc could be formed at all times, and, when properly formed would settle rapidly. Only after the delicate nature of the floc had been fully appreciated were the samples of floc taken from the trial filters of value. It was found that samples had to be taken most carefully in wide mouthed beakers, the beaker being slowly slipped around the sample so as not to disturb and break up the floc particles contained in it. Properly taken samples from the trial filter could then be fairly compared with those from the laboratory. Samples from the outlet of the mixing tanks before passing into the stilling chambers showed that the floc passing from the static mixing tanks was imperfect, consisting of varying sized particles, some large and settleable and some so small as to be practically non-settling. Careful comparisons of samples taken from the mixing chambers with those taken at the inlet end of the sedimentation tanks showed that the floc was being broken up during its passage through the round orifices in the walls of the stilling chamber. This was particularly noticeable on one day on which a mixture of ferric chloride

and alum had been used as a coagulant. The water containing fairly well formed particles of brown floc in the mixing chambers could be seen with the aid of a shaft of light issuing from the perforated openings into the sedimentation tanks in the form of a muddy brown water, the floc particles evidently having been dispersed by the jetting action produced in the restricted orifices between the two chambers.

RECONSTRUCTION OF THE TRIAL FILTER MIXING CHAMBERS

To determine whether the destruction of the floc in this way affected the length of filter run the top boards of the walls between the mixing chamber and settling tank were removed so that the water flowed from one into the other in a broad layer three inches in depth. Samples taken before and after at once showed that the destructive action due to the orifices had been eliminated and the floc particles were no longer being dispersed. The immediate effect was an increase in the normal length of filter run of from 5 to 6 hours to 10 and 12 hours. Samples of sludge collected in graduates in the tank so altered showed an increased amount of sludge settling out in the improved tank. Samples of the water passing over into the filters also showed that 67 percent of the floc was being retained in the improved tank as against 50 percent retention in the control tank. The extra retention of 16 percent of the floc seemed to be responsible for doubling the length of filter run.

This matter of the destruction of floc by passage through restricted orifices having been satisfactorily settled attention was turned to improving floc formation in the trial filter. Mixing for 20 minutes with the mechanical stirring apparatus which had been installed in the two mixing compartments of Filter No. 1 at various speeds and with three kinds of blades did not prove successful. An attempt was made to increase the 20 to a 40 minute mixing period by passing the treated water from mixing tanks No. 2 through a pipe into mixing tanks No. 1, but, although the results showed promise, there was still too much fine floc passing through. Short circuiting was suspected and a solution of a red diamond dye was poured into the inlet end of tank No. 2. Color immediately appeared in the second mixing compartment of tank No. 2, and in 9 minutes, instead of 40, the color had passed right through the four mixing compartments into the sedimentation tank. This conclusively proved that some of the water was only receiving 9 minute mixing when the four compartments were operating and less than half that time when only the two

mixing compartments were in use. Furthermore colored currents were traced through the sedimentation tank in 21 minutes instead of three hours and forty minutes. Currents showed distinct layering and color kept passing through for another 6 hours.

Having been satisfied that defective floc formation in the mixing tanks was due to too short a period of mixing because of short circuiting it was determined to remodel the mixing and stilling chambers.

DESCRIPTION OF ORIGINAL MIXING CHAMBERS

The concrete trial filters were two in number, each 35 feet 8 inches long by 5 feet wide by 9 feet deep and completely separated from each other by a concrete wall 8 inches thick. Each filter was 4 feet by 5 feet square and separated from the adjacent sedimentation tank by a concrete wall. The remainder of each filter was subdivided at the inlet end by two transverse wooden partitions into three compartments. The first was a mixing compartment 5 feet by $2\frac{1}{2}$ feet by $9\frac{1}{2}$ feet deep which was subdivided by a longitudinal wall to make two mixing chambers each $2\frac{1}{2}$ feet by $2\frac{1}{2}$ feet by $9\frac{1}{2}$ feet. The second compartment was a stilling chamber 5 feet by $1\frac{1}{4}$ feet by $9\frac{1}{2}$ feet and the third compartment the sedimentation tank proper 23 feet by 5 feet by $9\frac{1}{2}$ feet.

The water previously treated with coagulant entered the first mixing compartment through a pipe on one side which gave to the water in the tank a rotary motion. The water descended spirally to the bottom and passed through a hole on one side of the wooden partition into the second chamber and again rose to the surface with a spiral motion. From the second mixing compartment it passed in to the stilling chamber through a single opening and from that through two wooden diffusers perforated with rows of $\frac{1}{2}$- and 1-inch holes into the sedimentation tank in which the floc was supposed to settle to the bottom.

A head of 2 to 4 inches maintained on the first mixing chamber was sufficient to generate a spiral flow of about one foot a second and the time of passage through the mixing and stilling chambers was designed at 25 minutes. It was hoped that the perforated orifices into and from the stilling chambers would not only distribute the flow evenly over the whole cross section of the sedimentation tank but improve floc formation, a hope that was not realized in practice.

FILTER SAND

The sand used in the trial filters came from Cape May. It had an effective size of 0.5 millimeters and a uniformity coefficient of 1.6. Twenty-eight inches of this sand was used over 16 inches of graded gravel. The usual procedure was to clean out the whole of the filter system including pumps, pipe lines, mixing and sedimentation tanks every two weeks at which time the filter sand itself was scoured with a jet of water from a hose under high pressure. This was necessary to prevent any tendency to form mud balls and to make up for ineffective washing in the corners of the filters. The usual practice when washing back the filters was to use a 24-inch rise and wash for a period of 2½ minutes. This procedure together with special washing at the end of every two weeks proved to be sufficient to keep the filter sand in first class condition.

DESCRIPTION OF REDESIGNED MIXING CHAMBERS

In place of the original mixing device, consisting of two chambers followed by diffusers, four mixing chambers were constructed followed by a diffuser chamber. Particular attention was given to making the walls of these chambers perfectly water-tight to avoid short circuiting. Each mixing chamber was 2½ feet square. The treated water entered at the top of chamber No. 1, descended spirally to the bottom and passed into chamber No. 2 through an opening 3¼ inches square, then rose to the top with a spiral motion passing into chamber No. 3 at the top through an opening 3¼ inches square, then descended with the same motion to the bottom, passed into chamber No. 4 through a similar sized opening and again rose to the surface still rotating. From the top of chamber No. 4 it passed over a weir the full width of the chamber (2½ feet) in a flow 3 inches deep into a diffusion chamber 5 feet by 1 foot by 9½ feet. From this diffuser chamber it passed into the sedimentation tank through 4 slots extending across the full width of the tank each slot 1 inch deep. The top slot was 8 inches below the surface and the others at 1 foot intervals in depth. Hinged doors were used to cover these slots when necessary and could be adjusted at any angle by adjustable rods. Rearranged in this manner the system was put into operation on July 15 with all the doors into the sedimentation tank open. Filter No. 2 was run as before with the two mixing chambers and original perforated diffusers. The first runs on redesigned filter No. 1 were 20 hours and on No. 2 filter operating as before less than 6 hours.

FLOC PRODUCED AND HOW IT SETTLES IN THE REDESIGNED PLANT

Samples taken from the various mixing compartments and settling tank at once showed a remarkable improvement in floc formation. The floc particles were now large, uniform in size and settled more rapidly while non-settling particles were absent. The floc, in fact, compared favourably with the best that could be produced in the laboratory. The result of this improved floc formation was that more floc settled in the settling tanks. Enlarging the openings between the mixing chambers still further improved the quality of

TABLE 10

HOUR	PERCENTAGE REMOVAL IN NO. 1 SEDIMENTATION TANK
7 p.m.	60
9 p.m.	66⅔
11 p.m.	75
1 a.m.	85
3 a.m.	85
5 a.m.	85
7 a.m.	85
9 a.m.	85

TABLE 11

FILTER NO. 1		FLOC REMOVAL	FILTER NO. 2		FLOC REMOVAL
hours	*minutes*	*percent*	*hours*	*minutes*	*percent*
30	10	85–90	31	45	85–90
26	25	85–90	24	20	85–90
24	10	85–90	36	35	85–90
37	35	85–90	38	20	85–90
34	50	85–90	33	12	85–90

the floc delivered into the settling tanks so that even more of it settled out and less passed over to the filters. The improvement in floc settling is shown by table 10 based on the color test.

The filters were run in the same manner for several runs and No. 1 averaged about 23 hours while No. 2 averaged 3 hours, the weather being very hot at the time. In tank No. 1 floc removal was between 80 and 85 percent and in No. 2 between 50 and 60.

The results were so satisfactory that on July 22nd, No. 2 filter was shut down and remodelled in exactly the same way as No. 1.

The first runs are shown in table 11.

No difference could be observed in the currents or in the settling of the floc due to closing the doors or covering some of the slots in one tank and comparing the results obtained with those from the other with all doors open. During this period the water was steadily warming up and on hot days the increase in the temperature of the raw river water was sufficient to cause it to float along the top of the sedimentation tanks and carry more floc on to the filters, with the result that filter runs were not as long as during cloudy days. Runs of approximately 60 hours were obtained on both filters on one occasion with a final loss of head of 5.05 feet.

These results were highly satisfactory and indicated that we had solved the two difficult problems, first that of forming a rapidly settling floc without machinery and with practically no operating cost and second of inducing the floc so formed to settle out in the sedimentation tanks with the result that comparatively small amounts passed over to the filters.

After the mixing chambers had been redesigned and an excellent floc had been produced which was no longer broken up while passing into the sedimentation tanks, the filter runs were greatly lengthened due to the more complete settlement of floc in the sedimentation tanks. Although both filters gave much the same length of run during the same period the runs varied considerably in length, e.g., from 24 hours on July 28 to 60 on August 12.

COLLECTION OF SLUDGE

Before the development of our own colorimetric method we had no conception as to whether most of the floc was settling at the inlet or toward the outlet end nor the actual quantity of slude which was accumulating on the bottom of the tanks daily. To gather information on this point a number of 500 cc. graduates were suspended in the settling tanks by fine cord about three feet from the bottom along the centre line of the tanks and at regular intervals. As a rule these graduates were immersed about 5 P.M. and removed about 9 A.M. which gave a collecting period of 16 hours. The graduates were drawn up gently, allowed to stand for a few minutes in order to permit all the floc in the jars to settle and then the depth of sludge in the jars recorded. Curves made by charting these recordings on paper gave pictures of what was actually occurring at the bottom of the tanks. In fact when these nine or ten sludge collecting graduates were

placed side by side in their correct order a perfect miniature picture of how the sludge had settled on the bottom of the tank for the previous 16 hour period was shown by the sludge deposits in the bottom of the graduates.

After the coagulation tanks had been reconstructed it was found that, when using 2¾ grains of alum per gallon, the deposition of floc was fairly uniform over the whole length of the tank and amounted to 2.4 inches of sludge per day. This meant an accumulation of 2 feet of sludge in ten days unless the sludge should consolidate upon standing.

By actually siphoning off the supernatant fluid in the trial sedimentation tanks and measuring the sludge deposit it was found that these figures were correct and that two feet of sludge was deposited every ten days. As the tanks were cleaned out every two weeks their capacity was not seriously interfered with by this sludge accumulation.

Further confirmation of the quantity of sludge deposited in the sedimentation tanks was obtained by the use of a 9-foot glass cylinder 2 inches in diameter. This cylinder was lowered very slowly into the tank so as not to disturb the floc. When the cylinder touched bottom the top end was tightly corked and the cylinder slowly raised until the lower end was near the surface. A cork was then inserted in the lower end under water and the cylinder removed. In this way a core showing a perfect cross section of the contents of the tank at that particular place was secured and much interesting information was obtained as a result of taking many such cross sections. The depths of sludge obtained by these cores confirmed those obtained by means of suspended graduates and those by direct measurements amounting to 2.4 inches per day with 2¾ grains of alum per Imperial gallon and fifty hour filter runs.

CONSOLIDATION OF SETTLED SLUDGE

Nine foot cores of water from the sedimentation tanks with sludge 26 inches in depth at the bottom were allowed to settle for 24 hours. At the end of 3 hours the sludge had settled to 19 inches; in 5 hours to 18 inches; in 21 to 13½ inches and in 24 to 13 inches or a 50 percent reduction in volume. Should similar consolidation in the large sedimentation tanks take place on standng it would not be necessary to clean them so frequently. Accordingly one of the settling tanks containing 24 inches of sludge was shut off and allowed to settle for 90 hours and core samples withdrawn at intervals. Contrary to expe-

rience with glass cylinders the sludge in the tank did not consolidate at anything like the same rate. In fact 28½ inches of sludge consolidated to 24 inches in 26 hours and only to 20 inches in 90 hours. A far as the Ottawa river water is concerned the floc settling in the tanks builds up sludge at the rate of 2.4 inches a day with little tendency to consolidation. This particular sludge may act differently to other sludges loaded with inorganic turbidity and would differ from the sludge obtained with iron coagulants which tends to shrink.

CHARACTER OF SLUDGE

When the sludge valve in the centre of the bottom of the settling tank which contained 24 inches of sludge was opened slightly the waste pipe ran sludge for a few minutes only and then passed clear water. This, of course, is common experience with any kind of sludge and in sewage disposal has necessitated the development of various kinds of scrapers to drag the sludge to the sludge outlet.

Studies were made of this sludge in white procelain tanks about two feet square and one foot deep. After the sludge mixture had been allowed to settle, leaving about two inches of sludge on the bottom over a clear supernatant liquid, the sludge was siphoned off through ordinary laboratory rubber tubing. It was seen that a cone with comparatively steep slopes formed around the tube outlet leaving the white procelain visible for an inch around it. Sludge then ceased to flow and clear water only passed over. When the tube was gently withdrawn this cone remained as such for hours and the procelain at the bottom of the cone remained perfectly white. When the rubber end of the syphon was slowly moved backward and forward across the bottom all of the sludge could be picked up and removed without taking any of the supernatant fluid.

The sludge was just sticky enough to hold its shape, but a jet of water along the bottom to cut it or any mechanical stirring device would temporarily destroy its adhesive character and allow it to flow like water.

When the top liquid had been decanted from one of the large trial tanks until 2.5 feet of sludge only remained and the central sludge valve was opened a slight depression appeared over the outlet pipe and gradually deepened toward the centre and tapered off toward the end of the tank. Then the sludge could be seen flowing as it were slowly down this slope until removal was practically complete.

EFFECT OF SUNSHINE

Observations showed that on days on which the filter runs were short currents in the sedimentation tanks were more rapid and held much more floc in suspension than in periods in which filter runs were long. When currents were rapid there was much floc in suspension and a beam of light would not penetrate far into the tank; when currents were slow there was less suspended floc and an object could be seen at considerable depths.

Actual tests by our colorimetric method showed that in all cases there was progressively less floc in suspension towards the outlet end of the tanks, but that during longer runs the reduction in floc was more marked and less floc passed on to the filters.

Core samples taken in the 9 foot glass tube showed that during short runs there were large amounts and during long runs small amounts of floc in suspension near the surface of the sedimentation tanks.

All of these observations pointed to stratification of the water and indicated that during short runs the incoming current, instead of being distributed fairly well over the whole cross section of the tank was flowing in a shallower, and therefore a swifter current along the top, and by virtue of its speed was carrying over to the filter large quantities of floc which should have settled in the tanks.

It was noted that, even where the doors into the sedimentation tank were turned so as to deflect the inflow downward, the current during short runs came up to the surface carrying with it clouds of well formed floc, and that there were many counter currents and eddies and much confusion for the first ten feet at the inlet end of the tank. These cross currents gradually disappeared, eventually resolving themselves into one comparatively uniform but rapid flow. These disturbances reduced the effective sedimentation length of the tank, since comparatively little settling took place in these disturbed areas.

On the other hand during periods of long filter runs the currents containing the floc could be seen issuing from the slots and sinking toward the bottom leaving a comparatively clear undisturbed area at the inlet end. At no stage during such long runs did large quantities of floc come to the surface, the flow through the tank was much slower and disturbing currents were not in evidence.

Stratification was obviously due to different densities in the incom-

ing water due to variations in temperature. The temperature of the water at the top and bottom of the tanks were taken frequently, and, as expected, differences were found, the surface water being usually one half to one degree Centigrade warmer than that on the bottom.

Small fluctuations in temperature were observed during the course of each 24 hours and these daily variations caused the trouble.

Warmer water being less dense tends to float over the cooler water and this was what took place in the tanks. Disturbances of currents as a rule did not become noticeable until the middle of the afternoon unless it proved to be particularly warm on which occasions the river water warmed up more quickly, the disturbing currents began sooner and the effects lasted longer.

The following data show what happened on August 13 which was hot with bright sunshine all day.

HOUR	TEMPERATURE		
	River water	Surface of settling tanks	Bottom of settling tanks
	°C.	°C.	°C.
11 a.m.	20.5	20.2	
3 p.m.	20.8	20.6	20.3
4 p.m.	20.8	20.6	
5 p.m.	20.8	20.6	20.4

During that day the quantity of floc going on to the filter remained at 20 percent (80 percent removal) until by 4.30 p.m. the disturbance extended to the full length of the settling tank and the floc removal fell to 66⅔ percent. This continued till after 6 p.m. gradually decreasing until by 11 p.m. there was 85–90 percent removal once more.

The following day, August 14, was equally warm, but the sky was heavily overcast with clouds. The raw water on this day showed very little change in temperature.

HOUR	TEMPERATURE		
	River water	Surface of settling tanks	Bottom of settling tanks
	°C.	°C.	°C.
10 a.m.	20.3	20.3	20.2
3 p.m.	20.4	20.35	20.3
5 p.m.	20.4	20.4	20.4

On this day there was no evidence of floc disturbance in the tanks which indicated that it had been the direct rays of the sun on the water flowing in a shallow broad sheet over the Little Chaudiere Falls just above the intake which had heated up the water and caused all the trouble. These results were so constant that on looking back over the tabulated results one could pick out the dull, cloudy days by the increased lengths of filter runs.

Our hypothesis was proved to be correct in rather a striking manner on a day when these floc disturbances were at their height by chilling the water in the mixing chambers with blocks of ice. The currents coming to the top of the sedimentation tank suddenly began to slow down, hesitated and then sank toward the bottom so that one could see far into the tanks. As soon as the ice had melted and all the chilled water had passed through into the sedimentation tanks the incoming currents again made their way to the surface and continued as before to carry along clouds of floc to the filters.

Confirmation of the hypothesis was secured by adding about fifty gallons of hot water to the top of the middle of the sedimentation tanks while these disturbing currents were flowing along the surface. The incoming current with its contained floc passed underneath the warm layer and up again to the surface farther along, showing that the cooler denser water tended to pass toward the bottom under less dense warmer surface waters.

Late in the autumn as the water in the river became colder the same process occurred and the filter runs fell to less than 15 hours. In this case the river water was about 34°F. and as water at 39°F. is at its greatest density the colder incoming lighter water tended to flow along the surface, to carry its contained floc over to the filters and to shorten the length of filter run.

DEPTH OF FILTER SAND

Until August 15, each filter had been operating with 28 inches of sand in the filters. In order to see what the results would be with a deeper sand bed another 10 inches of sand was added to Filter No. 1 so that from August 15 to October, Filter No. 1 ran with 38 inches of sand and filter No. 2 with 28 inches of sand as before. For the first few days thereafter both filters gave the same length of filter runs, as follows

FILTER NO. 1		FILTER NO. 2	
Length of run	Loss of head	Length of run	Loss of head
hours	*feet*	*hours*	*feet*
66¼	4.15	64¾	4.875
51½	3.6	52¼	4.25
46¼	3.15	44½	2.90

After the third run No. 2 Filter was shut down for four days to carry on experiments in the consolidation of sludge while No. 1 Filter was kept running. After eleven days both filters were started at the same time on new runs and from that time the runs on Filter No. 1 which contained the deeper sand were invariably longer than those on Filter No. 2 as shown in table 12.

TABLE 12

FILTER NO. 1		FILTER NO. 2	
Length of run	Loss of head	Length of run	Loss of head
hours	*feet*	*hours*	*feet*
57¼	4.05	37¼	
67½	4.725	48	3.65
51¼	3.225	43½	3.325
46¼	2.775	26¾	2.125
41¾	3.05	38½	2.575
48	3.40	42¼	3.4
		27¼	2.175
52*	3.53*	37.6†	2.87*

* Average 6 runs.
† Average 7 runs.

This was an increase of 38 percent in the length of run for Filter No. 1 over Filter No. 2 during the same period for an increase in depth of sand of 35 percent.

The bacterial efficiency was also improved in the filter with the extra depth of sand right from the beginning.

From September 10 to September 21 both filters were run with 2½ grains of alum per gallon instead of 2¾ grains used up to that date. The results shown in table 13 were very similar to those obtained with 2¾ grains.

The next series of 6 runs were made using 2¾ grains of alum again.

On Filter No. 1 they average 51 hours and on Filter No. 2 they averaged 46. The next series gave 48¾ hours on Filter No. 1 and 33¾ on filter No. 2, while the following series gave 42½ hours for No. 1 and 30¾ for No. 2.

There seemed to be no doubt whatever, therefore, that the increased depth of filter sand was beneficial in considerably lengthening the filter run and improving the bacterial efficiency.

The whole of this experimental work was an excellent example of harmonious co-operative effort. The plant was recommended by A. F. Macallum, Commissioner of Works, and W. E. MacDonald, Water Works Engineer of Ottawa, under whose supervision the trial

TABLE 13

FILTER NO. 1		FILTER NO. 2	
Length of run	Loss of head at failure	Length of run	Loss of head at failure
hours	*feet*	*hours*	*feet*
47½	2.75	43¾	2.33
45¾	2.65	23½	1.60
46	2.71	21¾	1.54
48½	2.80	40½	3.13
44½	2.80	44	3.54
		35½	2.25
46½*	2.69	34¾*	2.17

* Average 5 runs.

filter was built. The trial filters themselves and certain special alum feed and other equipment were designed by William Gore of Gore, Nasmith and Storrie the Consulting Engineers, who also saw the plant put into operation. The operating personnel was supplied by the Department of Works under D. Stalker, Assistant Water Works Engineer, who also kept all operating records and had special equipment such as mechanical mixing equipment for the plant and laboratory built in the Works Department shops. The chemical and physical investigations were carried on by H. Scheak, resident chemist for the Consulting Engineers, while the operation of the plant and the investigations carried out were under the direction of the writer, who spent half of each week at the Ottawa Experimental Plant.

EQUIPMENT FOR ELECTRICALLY-DRIVEN PUMPING STATIONS[1]

By R. L. Baldwin[2]

Many small cities have direct pressure systems for water supply. Where steam driven pumps are used it is possible to vary the speed in proportion to the quantity of water required, thereby maintaining an even pressure.

Where motor driven units are in use it is difficult to maintain constant pressure, since the motor speed of standard equipment is constant. This means that pressure must vary with the discharge and that unfortunately when more pressure is required at high rates of discharge to compensate for friction losses, it is low or inadequate. Such installations are, therefore, handicapped with poor pressure regulation. High pressures must be carried at times when not needed in order to have an adequate pressure when large capacity is required. This in turn causes poor overall efficiency, often being from 30 to 40 percent and even less.

Where it is possible, the installation of elevated storage on the system solves this question and adds many other advantages. At the outset, the writer wishes it understood that the method of operation proposed in this paper is not a substitute for elevated storage, but that it does give a method of improving operation and economy at low cost and may serve in many cases where the use of elevated storage is not feasible.

The automatic operation of electric substations has become standard practice. It is much more complicated and there are many more variables encountered in its design than there would be in the design of an automatically controlled pumping station of the same importance. This paper is an application of the automatic method of operation to the pumping of water with particular attention to improvement of economy.

[1] Presented before the Toronto Convention, June 25, 1929.

[2] Of Burns and McDonnell Engineering Company, Kansas City, Kans.

The use of a variable speed motor may serve in some instances to drive a pumping unit and obtain reasonable efficiency. If a slipring motor is used, resistance must be used to obtain reduced speed. Ordinary operation must be at the reduced speed in order to have increased capacity at higher speed for peak demands. This means a high energy loss in the resistors in order to obtain this speed control and a corresponding low efficiency.

A motor of the brush shifting type offers good efficiency at all speeds, but it has serious speed limitations. The manufacturers have not encouraged its use for such service. Up to this time such a system has not been found economically feasible.

The use of pole changing devices for the variation of motor speed for this purpose causes too great a change in speed at each change. It has been used in some installations but is not generally suitable for a direct pressure system.

Boosters are often used where an increase in pressure is desired for short periods. In the ordinary system it is desired to maintain a satisfactory pressure on the distribution system. Very often a transmission main is required to convey the water from the pumping station to the distribution system and this involves high friction losses at times of maximum discharge. Boosters when used are usually designed for a fixed discharge and pressure to care for the maximum discharge and pressure desired.

Another method might be used, namely, two or three ordinary centrifugal pumps driven by constant speed motors with a booster of variable capacity and pressure designed to take care of friction losses. In this way the base load pumps could be operated at a maximum efficiency and the low efficiency would be on the booster pump alone. At low rates of discharge necessitating low speeds, the efficiency of the booster would be low but it would carry only a small portion of the load and hence would not affect much the overall efficiency. At the higher rate of discharge when the friction is increased and becomes a larger portion of the total load, then the higher speeds are required and the overall efficiency is better.

EXAMPLE OF PROVIDING PUMPING EQUIPMENT FOR VARIABLE LOAD

In order to determine the overall economy of pumping with such an arrangement, a case has been assumed where it is desired to maintain a pressure on the distribution system of approximately 160 feet head and not less than 140 feet head. The friction loss between

the pump station and the center of the distribution system has been assumed to vary from zero at no load to 100 feet at the maximum rate of discharge.

Operation on the flat portion of the head capacity curve for a centrifugal pump means fairly constant pressure, but the range of constant pressure operation with a single pump and with reasonable efficiency is very limited. Hence it is wise to use at least three units as they may be suited to the load more closely. An average pumpage of between 2 and 3 m.g.d. is assumed and standard single stage centrifugal pumps designed for heads and capacities as follow are used:

PUMP NUMBER	CAPACITY	HEAD	HORSEPOWER	MOTOR
	m.g.d.	*feet*		*r.p.m.*
1	1	160	50	1,800
2	2	175	75	1,800
3	3	160	100	1,800

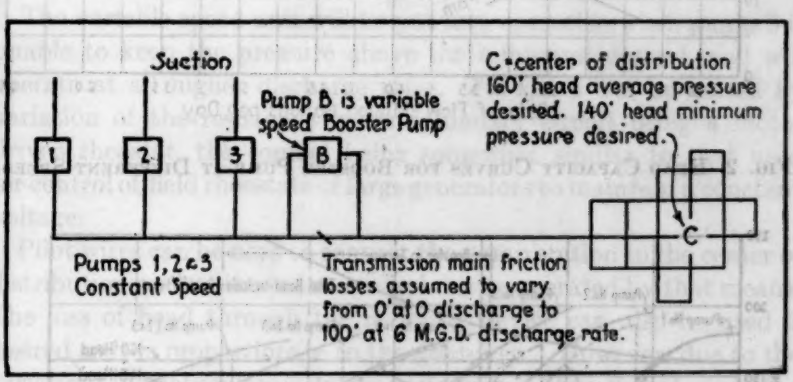
Suction
Pump B is variable speed Booster Pump
C=center of distribution 160' head average pressure desired. 140' head minimum pressure desired.
1
2
3
B
C
Pumps 1,2&3 Constant Speed
Transmission main friction losses assumed to vary from 0' at 0 discharge to 100' at 6 M.G.D. discharge rate.

FIG. 1. DIAGRAM OF SUGGESTED PUMPING STATION

The second is designed for a slightly higher head to take care of friction losses as it is desired not to connect the booster until more capacity is needed. The booster can use a standard centrifugal pump driven by wound rotor motor of 125 h.p. capacity, 1200 r.p.m. With the friction losses at various rates of discharge known a pump can be selected so that it can be operated to absorb exactly the friction losses by varying the speed of the motor as required.

All of these pumps and motors are standard pieces of apparatus and their operating economy can be readily obtained at various loads and speeds. Reference to figure 1 shows diagrammatically the

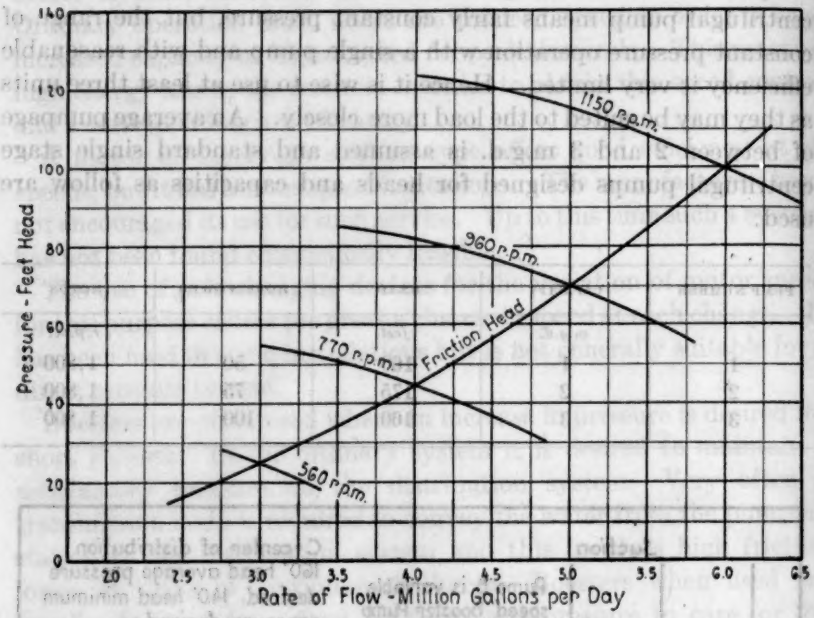

FIG. 2. HEAD CAPACITY CURVES FOR BOOSTER PUMP AT DIFFERENT SPEEDS

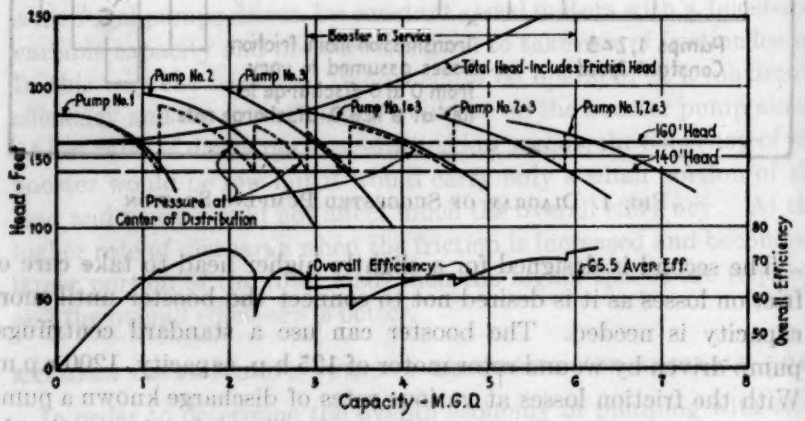

FIG. 3. HEAD CAPACITY AND EFFICIENCY CURVES FOR COMBINATION OF PUMPS WITH BOOSTER TO CARE FOR FRICTION LOSSES

assumed layout. Figure 2 shows curves giving the characteristics of the booster pump at different speeds. The same data for the constant speed pumps are given in figure 3.

Method of control

By proper selection of the head capacity characteristics of the two small centrifugal pumps the pressure at the center of distribution may be maintained within reasonable limits without the expedient of the variable speed unit. These two units may be brought into operation or taken out of operation as may be desired by means of a pressure regulator type of control—pump 1 being cut out of operation when pump 2 is started. For this combination of pumps the rates of discharge at which pumps are started and stopped are shown on figure 3. The minimum pressure desired at the center of distribution determines the rate of discharge at which each pump is put into service. In this case a new pump of greater capacity is started when the pressure maintained at the center of distribution drops to 140 feet head.

The variable speed unit will be put into operation when pump 3 is unable to keep the pressure above the minimum desired, and will operate at all higher discharge rates. Its speed can be varied by variation of the resistance in its secondary circuit using a motor driven rheostat, the control being somewhat similar to that used for control of field rheostats of large generators to maintain a constant voltage.

Pilot wires can be used to connect the pump station to the center of distribution so that the entire control can be operated by that means. The loss of head through the metering device can also be used if desired as it is proportionate to the discharge. However, due to the variations in friction losses due to variations in the point of use in the distribution system, the method of using the pressure at the center of the distribution for control is preferred.

CALCULATION OF EFFICIENCY OF OPERATION

The efficiency for any discharge up to the rate at which the booster is cut into operation can be easily obtained from the ordinary data obtainable for both pumps and motors. When the booster is in service, the losses in the rheostat must be added to the losses in the motor. In order to make this study of efficiencies, an operating

scheme must be set up for the different pumping units. Table 1 shows the pumps operating for various rates of discharge desired, with the efficiencies for the pump operating or the combined efficiency if two or more pumps are operating, the water horsepower developed and the total losses expressed in horsepower.

Table 2 shows the operating data for the variable speed unit. It gives the speed for different rates of discharge, the water horsepower, the power input and the total losses expressed in horsepower.

TABLE 1

Operating data for constant speed pumping units

RATE OF PUMPING	PUMP OPERATING NUMBERS	COMBINED EFFICIENCIES OF PUMPS OPERATING	WATER HORSEPOWER DEVELOPED W-1	TOTAL LOSSES OF UNIT IN HORSEPOWER L-1
m.g.d.				
0	1	0	0	
0.8	1	65	23.9	15.9
1.2	1	75	30.2	14.2
1.2	2	75	40.3	19.5
1.6	2	81	51.5	19.1
2.0	2	82	59.0	20.7
2.3	2	75	63.5	30.4
2.3	3	60	74.3	63.0
2.6	3	73	79.5	36.5
2.9	3	79	84.5	34.3
3.4	3	80	86.0	31.0
3.4	1–3	79	103.0	63.0
4.0	1–3	79.5	111.0	44.6
4.6	1–3	80–0	117.0	45.5
4.6	2–3	74.0	142.0	71.0
5.2	2–3	78.7	145.0	60.6
5.6	2–3	76.5	142.0	63.6
5.9	2–3	74.0	140.0	70.0
5.9	1–2–3	78.0	165.0	70.0
6.0	1–2–3	78.3	172.0	72.3

The total overall efficiency of the pumping installation is defined here as the ratio of the total water horsepower to the total power used by the motors, including all resistance losses. Table 3 gives the total water horsepower which is the sum of columns designated as W-1 and W-2 in tables 1 and 2. The column marked total losses is the sum of the losses for the constant speed pump and the variable speed pump given in tables 1 and 2 under columns designated as L-1 and L-2.

TABLE 2

Operating data for variable speed unit

RATE OF PUMPING	MOTOR SPEED	WATER HORSEPOWER DEVELOPED W-2	POWER INPUT, HORSEPOWER	TOTAL LOSSES OF UNIT IN HORSEPOWER L-2
m.g.d	*r.p.m.*			
2.9	540	12.1	16.2	24.0
3.4	640	18.9	24.0	30.0
4.0	770	30.6	37.0	32.0
4.6	830	47.8	58.3	38.1
5.2	1,000	68.0	82.0	34.0
5.6	1,060	84.5	101.0	29.5
5.9	1,130	99.9	119.0	29.1
6.0	1,150	105.0	125.0	29.0

TABLE 3

Overall efficiency

1	2	3	4	5	6
RATE OF PUMPING	PUMP OPERATING NUMBERS	TOTAL WATER, HORSEPOWER 3 = W1 + W2	TOTAL LOSSES, HORSEPOWER 4 = L1 + L2	POWER INPUT, HORSEPOWER 5 = Col. 3 + Col. 4	OVERALL EFFICIENCY 6 = Col. 3/Col. 5
m.g.d.					*per cent*
0.8	1	23.9	15.9	39.8	60.2
1.2	1	30.2	14.2	44.4	68.1
1.2	2	40.3	19.5	59.8	67.5
1.6	2	51.5	19.1	70.6	71.6
2.0	2	59.0	20.7	79.7	74.0
2.3	2	63.5	30.4	93.9	67.5
2.3	3	74.3	63.0	137.3	54.5
2.6	3	79.5	36.5	116.0	68.5
2.9	3	84.5	34.3	118.8	65.6
2.9	3-B	96.6	58.3	154.9	62.4
3.4	3-B	104.9	61.0	165.9	63.3
3.4	1-3-B	121.9	93.0	214.9	56.8
4.0	1-3-B	141.6	76.6	218.2	64.6
4.6	1-3-B	164.8	83.6	248.4	66.2
4.6	2-3-B	189.8	109.1	298.9	63.8
5.2	2-3-B	213.0	94.6	307.6	69.2
5.6	2-3-B	226.5	93.1	319.6	71.0
5.9	2-3-B	239.9	99.1	339.0	70.8
5.9	1-2-3-B	264.9	99.1	364.0	72.5
6.0	1-2-3-B	277.0	101.3	378.3	73.2

The water horsepower plus the losses gives the total power required for each rate of discharge and from these data the overall efficiency is calculated and is tabulated in the last column in table 3.

CONCLUSIONS

Possibly better economy could have been obtained at some points by making some slight changes in the pumps selected for this particular case. However the results obtained from this study are such an improvement over the ordinary direct pressure centrifugal pumping installation that it deserves full consideration when there are limited funds available for improvements.

If it is necessary in some cases to operate centrifugal pumping stations on a direct pressure system with the resulting low economy usually obtained it certainly behooves engineers and waterworks operators to seek some method of improving the conditions. The efficiency indicated here is approximately 65 percent overall while present operation of direct pressure motor driven stations is approximately one-half this.

The automatic feature of operation is saving in labor, but above all else it insures that the right pump is operating to obtain the best economy. Where the control is manual, pumps will not be started and stopped at the correct time. Less disturbance to electric and water systems is caused by automatic starting and stopping because it is done in the proper manner and at the correct time.

THE DIESEL ENGINE AS AN ECONOMIC FACTOR IN PUMPING[1]

By C. T. Baker[2]

Several different types of prime movers are available for supplying power to pumps of all sizes and classes and it is recognized by engineers that the selection of the kind of power which will best meet any given condition of service will depend principally upon existing local conditions.

Until about 1900, steam operated pumps predominated and while the builders supplied many different types of pumps, even in the early days of the industry, yet steam furnished the motive power in the majority of installations.

With the advent of the electric motor, however, a new era in pumping methods appeared, which within a few years had completely revolutionized pumping practices in so far as the application of power to pumping was concerned.

At first the direct current motor was used which generally employed a belt for transmitting power from motor to pump. Then came the polyphase alternating current motor which ultimately succeeded in overthrowing the great wall of prejudice surrounding this type motor that had been erected by the "dyed-in-the-wool" advocates of the direct current machines. This proved a great boon to pumping by electricity since the A.C. motor possessed many advantages not found in the D.C. machine and, therefore, permitted a wide range of usage not possible with the earlier type motor.

For example, the A.C. motor may be used for direct connection to centrifugal pumps for all speeds within the operating range of such pumps without the necessity for speed changers of any character.

THE DIESEL DRIVE

In more recent years another type of prime mover has come into quite general use for driving pumping units; a machine known as

[1] Presented before the Southeastern Section meeting, April 15, 1930.

[2] Consulting Engineer, Atlanta, Ga.

the oil engine, usually spoken of as the Diesel engine, so-called because of its inventor, Dr. Rudolph Diesel of Germany, who completed his first successful Diesel engine in 1897.

In the majority of earlier installations using oil engines for power in pumping operations the engine was connected to the pump by means of a belt, and even today this plan is followed occasionally. However, in recent years developments in Deisel pumping plants have departed from the belt drive, and the engine has been connected to the pump either through gears or other speed changing devices.

For example, in the case of duplex plunger pumps the engine shaft is coupled to the main pump shaft which is in turn geared to the plunger crank shaft, thus permitting the economical engine speed without interfering with the required pump speed.

This type of drive has been successfully applied for pumping water as well as for heavy duty oil line pump service common in the oil producing sections of the country.

Still another type of oil engine driven pumping installation has been that of the large triplex plunger pump with the engine directly connected to the main pump shaft through a flexible coupling.

One such plant as this is employed by an Eastern railroad pumping plant which has a capacity of 2.5 m.g.d.

In irrigation work in the southwest, some very successful Diesel driven pumping units have been in service for many years. One which the writer recalls is a 5,000 gallon per minute centrifugal pump driven by a 365 H.P. engine. This pump supplies water under low head service for general irrigation purposes.

Another, but larger installation requiring a 2,000 H.P. engine, has been used for similar service with entirely satisfactory results for several years.

In the case of the high-speed centrifugal pump which requires speeds beyond the ordinary engine speeds, it is, of course, necessary to make use of speed changing devices that will permit of the proper speed ratios between engine and pump. Such devices, however, are not only highly efficient, but are absolutely dependable and with proper care exercised when installing the combined unit, no difficulty need be experienced.

In other cases, eminently satisfactory pumping plants have been built in which Diesel engines have been directly connected to alternating current generators which generate current at 2300 volts, supplying such current to motor driven centrifugal pumps through the usual switchboard and starting arrangement.

This plan has many advantages in certain cases, since it supplies power that may be used for a number of pumps and for other purposes as well. Usually much greater flexibility of operation is possible where Diesel power is first converted to electric power and then applied to pumps through the use of electric motors.

As to whether or not this plan should be followed will obviously depend upon local conditions and just what is required in the way of flexibility, load factor, etc.

The more economical arrangement is with the direct connected engine and pump, since by this arrangement generator and motor losses are eliminated, which on the whole will represent a saving in power of from 17 to 20 percent. A word of caution, however, appears apropos at this juncture, and that is, the selection of the method of applying Diesel power in any given case should not be made until after the location's conditions have been carefully analyzed. Otherwise the best plan may not be selected.

It should be pointed out also, that in the case of either Diesel electric drive or direct Diesel drive as described, any pumping condition can be satisfactorily met both as regards capacity and head that can be met with any other type of drive. Consequently no one need hesitate even when considering pumping installations which operate in the region of high capacities and high heads, to consider Diesel drive.

PUMPING COSTS

One of the principal reasons for using oil engines as prime movers in pumping operations is that the economic results possible with such drives are, all things considered, such as first cost, interest, depreciation, maintenance, etc., usually much better than with other types of drive. Operating records of many municipal and privately owned pumping plants will support this statement.

It is interesting to compare the figures of average consumption of heat units of the various types of prime movers used for power generation in both industrial and central station plants.

The data in table 1 reflect clearly the thermal results which may be expected or realized from the different prime movers.

It is worthy of note that the B.t.u. consumption with Diesel engines is substantially the same at all loads from one-half to full load. In other words, the fuel consumption curve from one-half to full load is very nearly a straight line, whereas, with other types of prime

movers the B.t.u. consumption curve swings sharply upward from the three-quarter lead value.

For example, selecting the simple non-condensing Corliss engine and the Diesel engine, we find that for the steam engine the B.t.u. consumption per B.H.P. at 25 percent load is 130,000, whereas with the Diesel engine at the same loading the B.t.u. consumption is approximately 13,000 per B.H.P. Of course, neither steam nor

TABLE 1

B.T.U. consumed per brake horsepower

	FULL LOAD	THREE-QUARTER LOAD
Simple non-condensing Corliss engine	52,000	58,000
Compound condensing Corliss engine	25,000	28,000
Steam turbine	20,000	23,000
Oil engine	8,000	9,000

TABLE 2

Cost data on pumping in a Florida plant

Oil engine pumping cost:	
Time pumped—265 hours—34 minutes	
Total gallons of water pumped—33,461,400	
Fuel consumed—1,531 gallons @ 7 cents	$107.17
Lubricating oil—32½ gallons @ 40 cents	12.85
Kerosene oil—25 gallons @ 18 cents	4.50
Total pumping cost for 30 days	$124.52
Cost of purchased power for an approximately equal period of time:	
Time pumped—261 hours—56 minutes	
Gallons of water pumped—33,003,600	
Cost of electricity per K.W.H. @ $3\frac{1}{16}$ cents	$551.25
Or in round numbers a saving of $427.00 in favor of Diesel power	

Diesel engines are operated at 25 percent load, but these latter figures are merely cited to show how nearly flat the fuel consumption curve of the Diesel engine is as compared with other types of prime movers.

In a city water works plant in Florida, the cost figures in table 2 have been taken from their operating records, showing a comparison between the cost of pumping based on purchased current and cost of pumping based on Diesel drive. This happens to be a plant where both purchased power and power generated on the premises are used.

Where current is generated with Diesel engines and is supplied to motor driven pumping units such as used in the average municipal pumping station, it has been found that with oil costing 4 cents a gallon and with pumps handling water against heads ranging from 90 to 125 pounds per square inch, the pumping cost will fall somewhere between $7.00 and $7.50 per million gallons pumped, where the operating load factor is 80 percent or slightly better.

KIND OF FUEL

The question is frequently asked; "What kind of oil may be used in the modern oil engine of today?" In answering this question I will quote from a paper which I wrote several years ago, and which was presented before another society, and which is still as true today as at that time:

"This modern oil engine will burn successfully a wide range of oils, including petroleum products of various kinds, from the lightest oils to the semi-fluid residues. However, it is not always advisable to attempt too wide a range in the use of fuel oils, and generally it is not good practice to use the semi-fluid oils or other heavy oils that may require considerable pre-heating external to the engine cylinders to render them sufficiently fluid to be handled by the fuel pumps. The matter of the kind of fuel to use for any given locality can, I believe, be best determined by a consideration of the joint advices and recommendations of the oil companies and the engine builders."

DISCUSSION

MR. ROBERTSON: What is the efficiency of the Diesel Engine?

MR. BAKER: Thirty-two percent. If you buy an engine from any reputable manufacturer you can get a guaranteed thermal efficiency of from 31 to 33 percent.

MR. COLLINS: What about repairs?

MR. BAKER: About, 2 to 2.5 percent, or somewhere in that neighborhood. I have found some plants which, the first year, have spent nothing. However, when a man runs any kind of equipment 3 or 4 years without any expense, the chances are that he has overlooked something; so it is necessary to take care of these things as they develop.

MR. SUDLOW: You consider 2 percent sufficient?

MR. BAKER: Yes. At the present time it is somewhat lower than in the past—depending upon the quality of your equipment. Some Diesel engines use solid injection, some air injection. It is a debatable question. Both are good and it is a matter very largely of individual choice. Diesel engineers of Germany have built engines of from 5000 to 7000 horse power. There is a great deal of research work being done and the results have been very favorable. As the use of this type of engine increases we may buy Diesel engines more cheaply. One of the troubles years ago, was the breaking of crank-shafts, but we have learned much more about crank-shafts and this trouble has been largely overcome. Crank failure today is the exception and not the rule.

A PRACTICABLE PROGRAM FOR THE ELIMINATION AND CONTROL OF CROSS CONNECTIONS[1]

By C. W. Mowry[2]

The object of this paper is to summarize in concise form the accumulated experience of fifteen years with this problem of cross connections between potable and non-potable water supplies.

First, I shall explain briefly why and how cross-connections have been made, and then shall outline practicable methods of eliminating the great majority of cross-connections and of safe-guarding the relatively few that it may be found necessary to retain.

Cross connections have been made for several reasons. One reason is that potable water supplies are usually too costly to use in large quantities for industrial purposes,—such as condensing, operating hydraulic elevators, toilet supplies, bleaching, dyeing, and other similar purposes. For many such industrial demands, it is customary to use available non-potable water supplies with the potable supply connected only for emergency use.

Another reason why cross connections have been made, beside the saving in cost of metered water, is that potable water supplies are liable to interruption at times. Therefore, to insure continuous service for such important purposes as feeding boilers, cooling electric furnaces, cooling large generator bearings, or for supplying automatic sprinklers, a secondary water supply is frequently held in reserve.

This feature of continuous service is especially important for an automatic sprinkler system, the efficiency of which depends upon having water always available at the sprinklers so that fire may be extinguished at the very start. Fire will not wait in case the water supply should be out of service. Public water systems are the very best primary supplies for automatic sprinklers; but occasionally even they are interrupted. We have a record of about four hundred

[1] Presented before the Florida Section meeting, April 10, 1930.

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failures or major interruptions of public water supplies.[3] In thirty of these instances, fire broke out during the interruption. Therefore, when large values are concentrated in industrial plants, mercantile buildings, and warehouses, a secondary water supply for the sprinklers is usually provided.

Still another reason for making cross connections, in addition to reducing cost and insuring continuous service, is that potable water supplies are frequently inadequate in pressure or volume to cope with a serious fire. Practically every large city in the country maintains steam fire engines or automobile pumpers to boost the city hydrant-pressure or to supplement the volume available from the potable supply, by taking suction from rivers, ponds, or other convenient bodies of water. Large manufacturing concerns maintain their own permanently installed fire pumps for these same purposes.

These three objects, then, to save the cost of metered water, to insure continuity of service, and to obtain an adequate water supply for fire fighting, are the principal reasons *why* cross connections have been made.

Let us now turn our attention to *how* they are made. Figure 1 shows in diagrammatic form the piping arrangements of two typical cross connections between potable and non-potable water supplies.

Industrial cross connections such as the one shown at *B* are dangerous, first, because they are frequently protected only by ordinary gate valves manually controlled, as in this example; and second, because the industrial water supply is usually maintained continuously under pressure from the non-potable source during working hours, so that a leaky valve becomes a permanent hazard.

The figure also shows a typical fire-service cross connection. The private fire main supplying the fire hydrants *G* and sprinkler risers *E* is fed normally with potable water from the public mains. For an ordinary fire the potable water supply is usually sufficient. It is only in case of a severe fire that a fire department pumper might attach hose lines to *F* and thus make a temporary cross connection either from the public hydrants or from a non-potable source, or that the fire pump *C* would be operated to supplement the potable supply by drawing water from the secondary source and delivering it into the fire protective system.

To enable both the primary and secondary supplies to feed auto-

[3] Copy of pamphlet describing these failures will be sent on request.

matically into the common fire protective system, check valves are installed on city connection *D*. These fire-service connections from

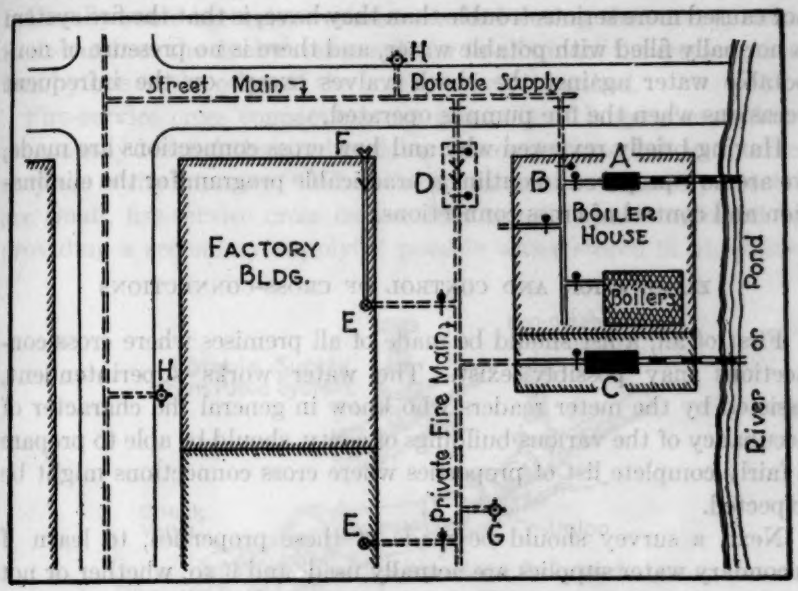

FIG. 1. SKETCH SHOWING TYPICAL INDUSTRIAL AND FIRE SERVICE CROSS CONNECTIONS

A—industrial pump taking suction from river, pond, or other non-potable source, to supply water for boiler feed, hydraulic elevators and general manufacturing purposes. *B*—cross connection between industrial-pump discharge and connection from public mains. This cross connection is controlled only by manually-operated gate-valves. *C*—fire pump taking suction from non-potable source for secondary supply to sprinklers and yard hydrants. This pump, normally idle, is operated only for test or fire. *D*—fire-service cross-connection from public main, protected by double all-bronze check valves located in a pit and regularly tested and cleaned. *E*—automatic-sprinkler supply-lines fed normally by potable water from public mains through cross connection D. Secondary supply from fire pump *C*. *F*—fire-department-connection to automatic sprinklers. By attaching hose lines to these inlets F, fire engines can make temporary cross connections by drawing water from street hydrants or from a non-potable source. *G*—private fire-hydrant supplied normally by potable water from public mains through cross connection D; and in emergency, by non-potable water from fire pump *C*. *H*—street fire-hydrants connected to public mains.

public mains are sometimes protected only by old-fashioned *single* iron-body check-valves, often buried in the ground and therefore

inaccessible. Rust gradually forms inside the valve bodies and hinders the free movement of the clappers, so that it is no wonder that some of these old valves have leaked. The reason that they have not caused more serious trouble than they have, is that the fire system is normally filled with potable water, and there is no pressure of non-potable water against the check valves except on the infrequent occasions when the fire pump is operated.

Having briefly reviewed why and how cross connections are made, we are now prepared to outline a practicable program for the elimination and control of cross connections.

ELIMINATION AND CONTROL OF CROSS-CONNECTIONS

First of all, a list should be made of all premises where cross connections may possibly exist. The water works superintendent, assisted by the meter readers who know in general the character of occupancy of the various buildings of a city, should be able to prepare a fairly complete list of properties where cross connections might be expected.

Next, a survey should be made of these properties, to learn if secondary water supplies are actually used, and if so, whether or not they are interconnected with the potable water supply. During the survey, the property owner or his engineer can point out or assist in locating all such cross connections.

By far the largest proportion of cross connections are for industrial and domestic use. Cross connections of this type, many of which are unknown and unprotected, usually can be eliminated because most industrial purposes require but one water supply at a time.

A simple and inexpensive method of eliminating industrial cross connections is illustrated by figure 2, which shows a flexible connection normally attached to one of the water supplies. In case of emergency, it can be disconnected and swung over to the other supply. By this method of elimination, *either* the primary or emergency water supply may be used as needed, but not *both* at the same time. This arrangement is especially adapted to situations where the two supplies are under pressure and do not require pumping.

Another method of eliminating industrial cross connections and one which is especially adapted to situations where the water has to be pumped, is by means of a small suction tank filled with potable water through a ball float-valve above the water level. This is illustrated

in figure 3. The service pump can deliver water from either the non-potable source or from the suction tank filled with potable water, without maintaining a cross connection.

Usually some agreement can be reached during the survey, either to discontinue the dual water supply, or to eliminate the cross-connection by one or the other of the methods just described.

Fire-service cross connections are generally of larger size and are more easily located than industrial cross connections, but in number they are in the minority. When the values or hazards to be protected are small, fire-service cross connections usually can be avoided by providing a secondary supply of potable water stored in an above-

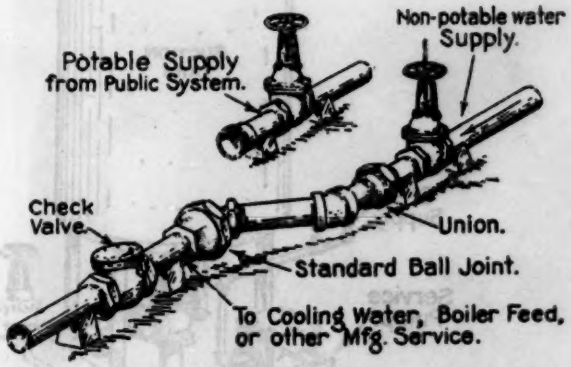

FIG. 2. METHOD OF ELIMINATING INDUSTRIAL CROSS CONNECTIONS

Swing joint for utilizing either potable or non-potable water as desired for industrial purposes, but not both supplies at the same time, thus eliminating cross connections. Not suitable for fire protective system.

ground steel suction-tank of capacity large enough to supply the fire pump for two hours or more as may be needed.

When, however, the hazards to life and property are large, it is not usually possible at any reasonable expense to store a sufficient amount of potable water to serve as an adequate primary or secondary supply. It was to meet these occasional, but important, situations that the double check valve arrangement was developed by the Factory Mutual Fire Insurance Companies in order to bring fire protection requirements into line with public health standards.

These modern check valves of the latest improved type are made entirely of bronze, so that all iron is eliminated and the accumulation

of rust is avoided. The valves are carefully made to jig and have liberal clearance around all moving parts. The rubber facing is of high-quality stock, and made rounded in section. As the pressure

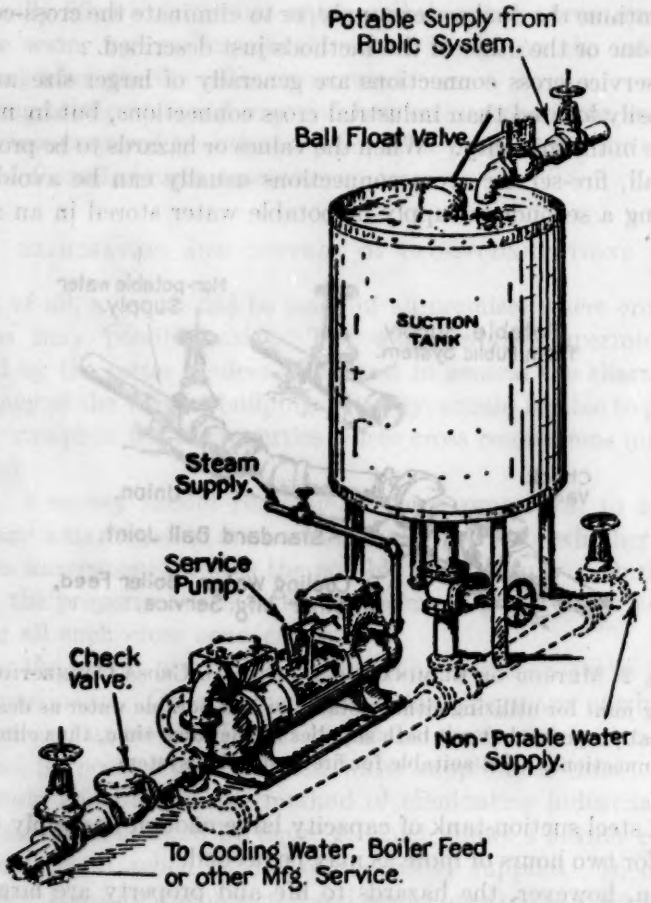

FIG. 3. METHOD OF ELIMINATING INDUSTRIAL CROSS CONNECTIONS

Another method of utilizing a potable and non-potable supply without cross connection. Potable supply is fed to a tank above water level, and is admitted automatically as desired by means of a ball float valve.

increases on the back of the clapper, the line of contact widens, and tightens the seal at the seat. Figure 4 shows the interior of one of these check valves.

Figure 5 shows a typical arrangement of a pair of these double

check valves arranged in series in a concrete pit with controlling gate valves, test gages and drains. Figure 6 is an actual photograph of this arrangement, and figure 7 is a cross section of a set of double check valves bolted together, showing the relation of the clappers to the drains and gages used for testing.

The efficiency of the double check valve equipment, as with any mechanical device, depends upon proper maintenance. The valves should be tested regularly and carefully for tightness and thoroughly cleaned inside annually. The inspectors of the Factory Mutual Companies test the check valves at all risks insured by them four times a year, and thoroughly clean the interiors once a year, replacing

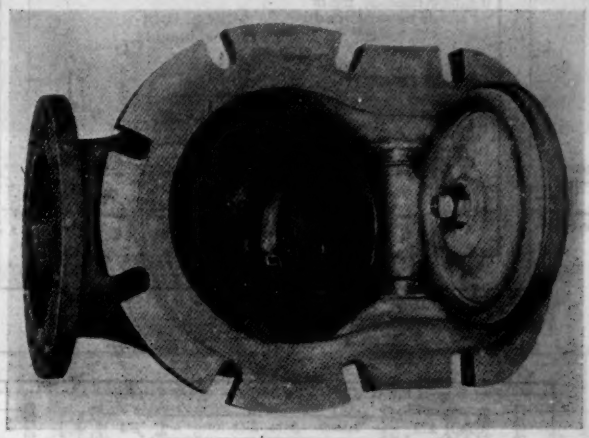

FIG. 4. VIEW LOOKING DIRECTLY DOWN INTO VALVE, WITH COVER REMOVED AND CLAPPER SWUNG CLEAR OUT OF BODY FOR INSPECTION AND CLEANING
Note slotted holes in cover flange and rounded rubber facing ring on clapper

the rubber facings as often as necessary. Permission to retain protected cross connections should be made contingent upon proper installation and careful maintenance of the double check valves.

During an experience covering fifteen years, we have never heard of a public water supply ever having become contaminated due to failure of any double check valve equipment.

As a still further safeguard, the fire pump can be provided with an automatic chlorinator so arranged that when the fire pump is started, the chlorinator will automatically begin to discharge chlorine into the fire pump suction at a rate sufficient to sterilize the water at the

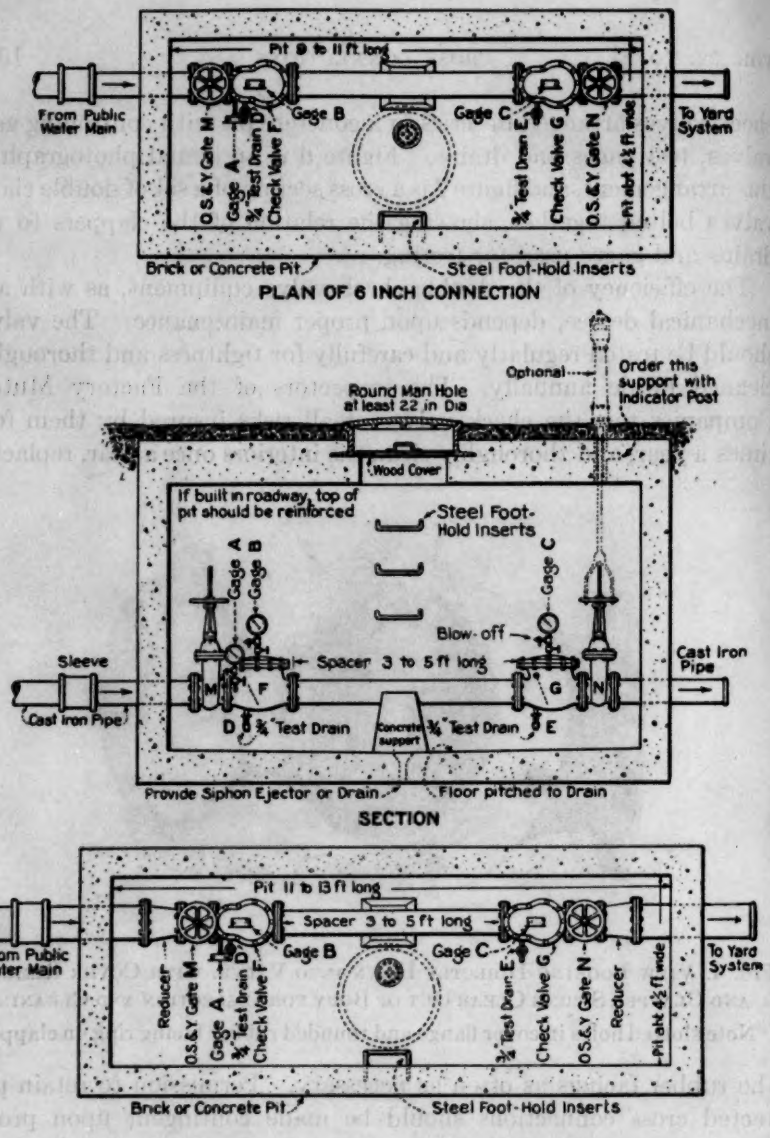

FIG. 5. DOUBLE CHECK VALVES IN CONCRETE PIT

Typical arrangement with spacer between check valves. Valves are bolted together when room is limited.

Referring to this figure, the valves are tested as follows: Close gate valve, *M*. Open test drain *D*, relieving pressure between gate *M* and clapper *F*. Pressure on gage *A* drops to zero. Pressure on gage *B* drops part way due to compression of rubber facing on clapper of check valve *F*. If gage *B* does not rise again to the same pressure as gage *C*, it proves that check *G* is tight. The test, however, is usually continued by opening drain *E*, allowing gage *B* to drop to zero.

A pamphlet describing the installation and maintenance of these double check valves will be sent upon request.

maximum rate of delivery of the pump. When the pump is idle, an auxiliary injector continually discharges a small amount of chlo-

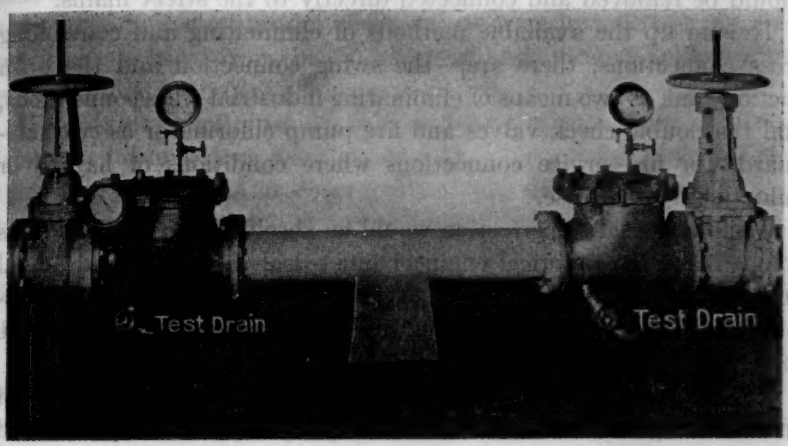

FIG. 6. A SET OF DOUBLE CHECK VALVES WITH SPACER BETWEEN
Note test cocks and pressure gages for quickly testing for tightness

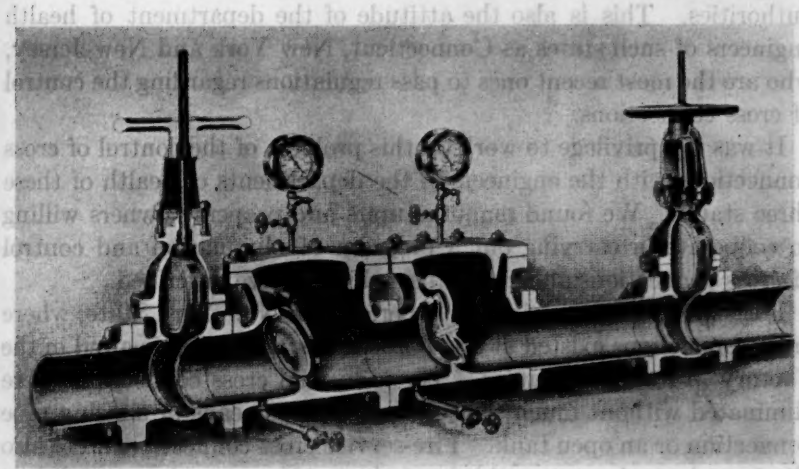

FIG. 7. INTERIOR OF A SET OF DOUBLE CHECK VALVES BOLTED TOGETHER
Showing relations of gages to clappers and to drains used for testing

rine to waste, thus keeping the apparatus primed and assuring that it is always in operative condition.[4]

[4] For detailed description of fire pump chlorinator, see report of Committee on Cross Connections, N. E. W. W. A. Proceedings, March, 1929.

Of course, any connections taken from a private fire system for supplying drinking water or for any other purpose but fire protection, should be removed and connected directly to the street mains.

To sum up the available methods of eliminating and controlling cross connections, there are,—the swing connection and the open suction-tank as two means of eliminating industrial cross connections, and the double check valves and fire pump chlorinator as two safeguards for fire-service connections where conditions of hazard or value justify their use.

While the ideal of perfection would be absolutely to prohibit cross connections, the practical engineer must deal with facts and actual field conditions as well as with ideals, and he sometimes finds it impossible to eliminate all fire-service cross connections without undue hazard to life and property.

This was the attitude of the Committee on Cross Connections of the New England Water Works Association, which recently reviewed this entire subject, and prepared resolutions which recognize the principle that the elimination and control of cross connections is a matter which should be left largely to the discretion of state health authorities. This is also the attitude of the department of health engineers of such states as Connecticut, New York and New Jersey, who are the most recent ones to pass regulations regarding the control of cross connections.

It was my privilege to work on this problem of the control of cross connections with the engineers of the departments of health of these three states. We found manufacturers and property owners willing to coöperate in carrying out a program of elimination and control of cross connections along the lines which I have described.

For example, let me cite our experience in New York State, where cross connections existed at about 160 industrial plants insured in the Factory Mutual Companies. The industrial cross connections were eliminated without much difficulty, either by means of a swing pipe connection or an open tank. Fire-service cross connections were also eliminated at about two-thirds of these 160 properties, as follows: At some plants, an elevated gravity tank was substituted for a weak public water supply. At others, suction reservoirs containing non-potable water were drained, cleaned out, made tight, and filled with potable water; and at still other plants, where the hazards or values were moderate, the non-potable secondary water supply was abandoned, and an above-ground steel suction-tank was provided and filled with the potable water for the fire-pump supply.

At the remaining one-third of these properties in New York State, that is, at about 50 plants, where the value and hazard was so great that unlimited primary and secondary water supplies were considered necessary, double all-bronze check valves were installed on the fire-service connections from the public mains, and automatic chlorinators were installed in the fire pump suctions.

We obtained similar results in New Jersey, where about 170 industrial cross connections were eliminated. Fire-service cross connections were eliminated at 35 properties, and all-bronze double check valves were installed at 100 properties which we insure.

In Connecticut, fire-service cross connections were eliminated at 34 properties and double check valves installed at 86 properties which we insure.

Such definite accomplished facts as these are my reasons for believing that the practices and methods outlined in this paper are reasonable and practicable.

MUNICIPAL WATER UTILITY ACCOUNTING[1]

By G. B. Schunke[2]

Historically we are engaged in an occupation almost as old as recorded history. Egypt, Chaldea and India give evidence that even the ancients had a marvelous conception of the scope and possibilities of water distribution, while the Roman aqueducts to this day are the delight of the antiquarian who can see nothing new under the sun.

In our own country we had in the year 1800 only 16 water works plants of which 15 were privately owned, and only one, that of Alexandria, Va., publicly owned. Today we have considerably above 10,000 communities having public water supplies. In our own field, the trend of the last century has been distinctly a shifting from private to municipal ownership. Of the 25 largest cities in the U. S., only one (Indianapolis) is now privately operated, the city of San Francisco having only within the last few months become a municipal utility.

The same holds true of the smaller communities and perhaps 80 percent or more of our urban centers now have municipally conducted water systems.

It is not the purpose of the writer to discuss the reasons impelling this change from one corporate entity to another except as it emphasizes the importance of the relation of proper accounting methods in this vast field of human endeavor.

REGULATION OF UTILITY ACCOUNTING METHODS

One of the most interesting phenomena of our modern civilization is the part that corporations play in present day affairs. The day of the individual, like that of the horse, is gone, and instead of individual ownership in large undertakings, we have collective ownership, both private and governmental.

Private corporations such as railroads and public utilities have long since been under strict, although benevolent regulation of state and

[1] Presented before the Pacific Northwest Section meeting, April 25, 1930.

[2] Utility Accountant, Water Department, Seattle, Wash.

federal governments. One form of regulation has been the standardization of accounting methods in order that a proper comparison might be made of the activities of corporations performing like public functions.

Municipal corporations have not been immune, and now most states require municipal water utilities to report their operations on forms and classifications as outlined by the several state commissions having jurisdiction in the matter.

While the municipalities have generally been free of state regulation as to rates and adequacy of service, they have nevertheless been required to make an annual report on forms prescribed by the state.

Insofar as uniformity is desirable for making comparisons these requirements are beneficial, but the great difficulty lies in the fact that operating conditions are by no means identical and, therefore, comparisons are sometimes apt to be odious and misleading.

FINANCIAL STRUCTURE OF MUNICIPAL WATER UTILITIES

Municipalities and their utilities, like individuals, are habitually "hard-up," and find it difficult to procure sufficient capital to meet the outlays necessary to provide for growth in this new empire. And yet it is essential for the proper development of a water system to have a plan whereby sufficient funds are made available to finance extensions as they are required.

In the earlier years the city or town would issue general bonds which were a lien on all the taxable wealth of the community in order to raise capital to construct and extend water systems.

Now capital is raised by issuing utility or revenue bonds based on the security of the water system only. This requirement makes it necessary to operate the plant as a going concern in an economical and efficient manner in order to inspire confidence in the sufficiency of the security offered for new capital.

In Seattle we raise new capital for extensions by

(*a*) utility bond issues
(*b*) creating local improvement districts and issuing bonds against abutting property for distribution mains and hydrants
(*c*) investing a part of our surplus or profit in extensions.

Where the water department is required to finance the construction, not only of pipelines, reservoirs, pump stations, and trunk mains, but of the entire distribution system, the strain is very severe. Being

a municipal enterprise it is likely to become involved in local politics, favoring certain localities at the expense of others. If the distribution system is financed by the abutting property the water rates may be kept stable and uniform and the financial credit of the department conserved.

Municipally owned water utilities theoretically, at least, are supposed to render service at cost or as near as may be. They are not under the necessity of earning dividends for their stockholders. It is more reprehensible, therefore, if the rate structure of a municipal utility is unstable with a constant tendency upwards. The root of the evil goes back to the fact that the capital set-up is unsatisfactory.

As long as all capital expenditures were financed by general lien bonds, the taxable wealth of the community at large, and not the utility itself, stood sponsor for the credit of the water system. This expedient can no longer be utilized because of the many calls in other directions for improvements, and the water system must now rely on the device of utility or revenue bonds.

In other words the corporate authorities issue bonds against the water consumer rather than against the tax payer as such.

No one has the right to obtain water service without paying for it, but the abuse consists of not treating every locality alike. Therefore, the method of providing for distribution mains by assessing the abutting property is, in my opinion, the most equitable yet devised.

This is important because of the tendency of cities in the west spreading out far and wide. We do not wish to be cramped, and love the wide open spaces. What is the result? We must lay water mains for miles and miles in front of property that is to be developed in the future. Seattle with a population of 400,000 has nearly 900 miles of water mains which exceed in length mains of the larger cities in the east having twice the population. Even when the abutting property pays for these mains, the system is required to operate and maintain them without sufficient revenue in sight for years to come. If then the department should be required, in addition, to pay interest and redemption of bonds on an investment that is not yet ready to earn it, this is in effect a penalty on other consumers or unjust discrimination.

The water rates should be so adjusted that all operating and maintenance expenses, interest charges, and serial retirement of bonded debt are provided for and a sufficient cash reserve set aside to meet any extraordinary emergency.

The amount written off as depreciation on the plant should be offset by sufficient new construction or retirement of debt out of revenues or earnings.

To plan for this requires the thorough balancing of income and outgo in the form of an annual budget.

In Washington, water departments are required by state laws to submit to the city council not later than July 10 a detailed statement of estimated revenues and expenditures for the ensuing year. Anticipated revenues must be recited in detail showing the amount expected to be earned in the following year.

About 80 percent of our income is derived from metered water rates; 3 percent from unmetered water sold to contractors on local improvements, primarily paving; 5 percent from water paid for by the general fund for municipal purposes, such as fire protection, street sprinkling, etc.; 5 percent from water service connections (taps); and 7 percent from miscellaneous sources, such as interest on sinking fund investments, rentals, and labor and material furnished to other departments. Following 15 years' experience, the average increase in revenues during that period will be about 5 percent for each succeeding year.

Likewise the expenditures for operating and maintenance, fixed charges, and new construction must be minutely itemized. Reference here to new construction, means only that portion which we expect to spend from current revenues.

The expenditures can never exceed the estimated revenues. It is, therefore, important to be conservative when attempting to estimate income, because under present conditions we are under constant necessity of keeping our estimated expenditures to the barest necessities.

We absolutely must live within our income. Considering the fact that for 22 years the water rates have remained the same, it is a source of satisfaction to the department that we have always been able to make ends meet.

This word "budget" will be a nightmare unless it is rigidly applied. Just like the individual goes aimlessly adrift who spends his income unwisely or without thought of the morrow, a water system can not be operated successfully whose responsible officials fail to allocate carefully receipts and expenditures.

The receipts of the department are derived in large part from water rates, and if these rates do not produce sufficient revenues to meet the expenditures above referred to, common honesty requires a re-

adjustment. This is very often distasteful to the corporate authorities, and operating deficits are created that hamper the proper operation of the plant.

Incidentally one of the difficulties encountered is the reluctance of the city or town to pay the water department for services rendered in providing fire protection, street sprinkling, sewer flushing, and water service for parks and public buildings.

Water utilities differ from other public utility enterprises because of the uneven demand for its product. For perhaps 3 or 4 months of the year there is a very heavy demand for water service, and this necessitates building sufficient supply lines, adequate pumping facilities, and sufficient storage to meet the demand during the peak load. If the service demand could be averaged the year around, the amount of capital investment required would be materially less.

Water department officials are, therefore, not under any obligation to endeavor to increase water sales, but under the constant necessity of providing sufficient equipment to meet the demand at the peak period. In other words, the sales end of the water game takes care of itself. This is not so with the expenses to be incurred in keeping the plant in good condition and just one lap ahead of any necessary call for water service that may be made upon it.

COMMERCIAL COST ACCOUNTING

For accounting purposes, the expenses incurred in operating a water plant, however large or small, fall into 6 categories, viz:

(1) Supply
(2) Distribution
(3) Commercial
(4) General or miscellaneous
(5) Depreciation
(6) Fixed charges (interest on funded debt)

The first two of these divisions of expense are again sub-divided into operating and maintenance expenses. In practice we often find it difficult to differentiate between operation and maintenance, and to the man in the smaller community, who must be both superintendent and bookkeeper, this often represents a real difficulty. Broadly speaking all expenditures incurred in keeping the consumer supplied with water are operating expenses, while expenses incurred in better serving the public with existing facilities are maintenance expenses. Let me illustrate:

The cost of operating a pumping station, the wages of the engineer in charge, the cost of power, coal or oil, would be operating expenses; but the cost of repainting the machinery or building would be a maintenance expense. The expenses incurred in the actual pumping operation would be operating expenses, whereas the expenses incurred enabling the continued and better operation would be classified as maintenance expenses.

On the Pacific Coast our water systems are of 2 types—gravity supply and those depending altogether on pumping. Those water plants enjoying a gravity supply use surface water only, while plants requiring pumped water entirely derive their source of supply from either surface or ground sources.

The classification of supply expenses in the latter type of plant are far more diverse than the former because of the expenses involved in filtration, sedimentation and pumping.

A detailed classification for operation and maintenance covering water plants which pump their supply from surface or ground sources would comprise the following general accounts:

(A) Source of Water Supply and Collecting

(1) Source of water supply and collecting labor
(2) Supplies and expenses
(3) Buildings, Fixtures and Grounds

(B) Purification

(1) Purification labor
(2) Supplies and expenses
(3) Buildings, fixtures and grounds

(C) Steam Power Pumping

(1) Boiler labor
(2) Fuel for boilers
(3) Water for boilers
(4) Steam purchased for power
(5) Pump labor
(6) Lubricants

(D) Hydraulic Power Pumping

(1) Pumping labor
(2) Lubricants
(3) Supplies and expenses
(4) Buildings, Fixtures and grounds

(E) Electric Power Pumping

(1) Electric current generated
(2) Electric current bought
(3) Pump labor
(4) Lubricants
(5) Buildings, Fixtures and Grounds

(F) Gas Power Pumping

(1) Gas purchased for power
(2) Pump labor
(3) Lubricants
(4) Buildings, Fixtures and grounds

In Seattle we have hydraulic and electric power only to furnish water for all elevations above 325 feet sea level and approximately 8 percent of our metered water consumption requires to be pumped.

Gravity system supply expenses are similarly classified as follows:

(a) Water shed expenses
(b) Headworks (intake) expenses, incl. chlorination
(c) Pipe line transmission expenses

It will thus be seen that systems relying upon pumped water alone require greater emphasis on supply expenses than do gravity systems. These accounts can be subdivided and detailed to any extent deemed desirable as occasion may require.

The distribution expenses commence at the reservoirs, and from this point on are common to all water plants of whatever type. The principal distribution accounts for operation and maintenance are as follows:

(a) Reservoirs and standpipes
(b) Mains
(c) Hydrants
(d) Gate valves
(e) Service connections
(f) Meters
(g) Store and shop expenses
(h) Utility equipment

It is in the distribution field that the water works man finds his greatest challenge to operate a plant economically and efficiently. Up to this point, gravity has brought water to the reservoirs or it has been put there by mechanical means. At this point proper and ade-

quate distribution and allocation of costs can be of great assistance to the management.

If our records and accounts teach us nothing, they are hardly worth while keeping.

For instance, which type of main or gate valve is the most efficient? Which type and make of meter is the least expensive to maintain? Which type of auto or truck is most efficient?

Possibly the superintendent's memory or instinct can give this information, but often we delude ourselves and find ourselves mistaken.

In a proper distribution of expenses, these facts will be disclosed impartially and the management does not have to rely on guess work or prejudice. Detailed daily reports of labor and material used in both supply and distribution should be the basis from which reliable cost data are compiled. Commercial expenses comprise the salaries and supplies of that part of the office in direct touch with the public. In a small plant it is relatively less important, but as the community grows the contacts become more numerous. In Seattle we classify expenditures under this heading as follows:

(1) Contracts
(2) Meter reading and service inspection
(3) Accounting
(4) Collecting
(5) Miscellaneous office expenses

This is a mechanical age in which machinery such as ditch diggers and air compressors have released much man power formerly necessary in water plants, and the tendency in office management is to substitute mechanical equipment for billing, adding, computing, and the keeping of records generally.

It is not my purpose to discuss particular types of office equipment, but that mechanical operations will altogether supersede manual methods in the office is a foregone conclusion. The greater the volume of business and the number of accounts, the greater the savings that can be effected in adopting mechanical methods of keeping records of consumers accounts receivable. Private utilities, as a rule, are more progressive, in adopting new methods in office management due to more freedom in their relations with employees, although in all fairness it must be said that they often pay a high price for pioneering in new experiments.

High pressure salesmanship is something that we all have to contend with, and if municipal utilities are slower in adopting new methods they at least have the benefit of having these methods thoroughly tested out before adopting them.

General expenses comprise salaries of executive officers, insurance, rents, employees retirement, damages to persons and property, etc..

Accrued depreciation is the expense written off every month and properly chargeable as an expense item, just as much as the wage of an employee. Depreciation is caused mainly by 3 factors:

(1) Wear and tear
(2) Obsolesence
(3) Inadequacy of equipment

The item of wear and tear is readily admitted because human experience teaches us that every thing eventually wears out.

Obsolescence is fortunately not so important a factor of depreciation in water systems as obtains in other utility fields because of the stability of the business. Inadequacy of equipment, however, is a factor to be reckoned with.

We have several abandoned reservoirs and reservoir sites in Seattle, as well as pump stations no longer adequate in the locations first selected. However wisely a plant may be designed, the time comes when the center of business or population has shifted, and equipment that was once considered adequate must be abandoned or retired.

It is very well to set up an item of expense called accrued depreciation, but unless sufficient cash is set aside as a reserve to take care of this item, or sufficient new construction is paid for out of revenues or capital liabilities retired in lieu thereof, we had better forget it because it is folly to charge an account that we never intend to repay. To prevent misunderstanding, I mean, of course, that depreciation should be set up, but that provision should be made as I have indicated.

It is not my purpose to discuss the various rates of depreciation that may be charged on the different parts of the plant. Opinions differ widely and engineering judgment must take into consideration local conditions as they may exist. In Seattle the average rate on $27,000,000 of plant is roughly 2 percent and varies from 1 to 20 percent depending upon the class and the kind of equipment.

Fixed charges both for interest and redemption must be met promptly. In the State of Washington these charges are a lien prior

even to wages, and we know that we may retain for operating use only what is left after these payments have been made.

We have heretofore generalized on expense accounts divided into 6 general groups. We must now consider capital or construction expenditures. In Seattle, this type of expenditure is largely in the hands of the Engineering Department, and, as before stated, all distribution mains constructed under the supervision of the City Engineer are paid for by local improvement districts. However, the allocation to proper accounts is under direct supervision of the accounting department.

The official classification of plant or construction accounts in Washington, will meet the requirements of the most exacting engineers and accountants and comprises the following:

FIXED ASSETS

A. Intangible Capital

P. 1 Organization
P. 2 Water Rights
P. 3 Other intangible capital

B. Tangible Capital

I. Lands used in operation of property

P. 4 Source of Supply and Collecting System lands
P. 5 Purification System land
P. 6 Pumping Station land
P. 7 Supply Transmission and Storage System land
P. 8 Distribution System land
P. 9 Stores Department land
P. 10 Utility Equipment land
P. 11 General Office land
P. 12 Other lands devoted to operation

II. Buildings, Fixtures and Grounds used in operation of property

P. 13 Source of Supply and Collecting System Bldgs., Fixt. and Gds.
P. 14 Purification System "
P. 15 Steam Power Pumping Plant "
P. 16 Hydraulic Power Pumping Plant "
P. 17 Electric Generation Plant "
P. 18 Electric Power Plant "
P. 19 Gas Power Plant "
P. 20 Supply, Transmission and Storage "
P. 21 Distribution Reservoirs, Tanks and Standpipes "
P. 22 Other Distribution System "

P. 23 Stores Department Bldgs., Fixt. and Gds.
P. 24 Utility Equipment "
P. 25 General Office "
P. 26 Other Bldgs. Fixtures and Grounds devoted to operation

III. Equipment

P. 27 Source of Water Supply and Collecting System equipment
P. 28 Purification System equipment
P. 29 Boiler Plant equipment
P. 30 Steam Power Pumping Plant equipment
P. 31 Hydraulic Power Pumping Plant equipment
P. 32 Electric Generation, transmission and transformation equipment
P. 33 Electric Power pumping plant equipment.
P. 34 Gas Producer equipment
P. 35 Gas power pumping plant equipment
P. 36 Supply, Transmission, Aqueduct and mains (pipe lines)
P. 37 Supply, Transmission, Reservoirs, Tanks and Standpipes
P. 38 Supply, Transmission, Telephones lines and equipment
P. 39 Distribution Reservoirs, tanks and standpipes
P. 40 Distribution Mains
P. 41 Hydrants
P. 42 Services (taps)
P. 43 Meters and Installation
P. 44 Fire Cisterns, basins, fountains and troughs,
P. 45 Distribution telephone lines and equipment
P. 46 Stores Department equipment
P. 47 General Shop equipment
P. 48 Utility Equipment (autos, trucks, etc.)
P. 49 Miscellaneous Equipment
P. 50 Office equipment
P. 51 Boarding House and Employees Dwelling Equipment

C. Undistributed Capital

I. Special Construction Expenditures

P. 52 Operations preliminary to special construction
P. 53 Special Construction engineering and superintendence
P. 54 Use of Special construction work equipment
P. 55 Special construction law expense
P. 56 Special construction, injuries and damages
P. 57 Special construction, insurance
P. 58 Special construction interest, premium and discount
P. 59 Special construction, miscellaneous expenditures
P. 60 Special construction, of plant
P. 61 Special construction work equipment
P. 62 Special construction, materials and supplies

When the construction under Undistributed Capital is completed, the amounts so expended are transferred to the proper construction or plant accounts.

PUBLIC RELATIONS

The subject of Public Relations of the water utility to the consumer is receiving increasing attention at every local and national gathering of water department officials.

Just as the "public be damned" attitude of private corporations of a generation ago has given way to a more enlightened view-point, the attitude of water department personnel toward the public has changed for the better. We realize more than ever before that good will is an asset. Although intangible, it is the most valuable and prized possession of our utility.

The very monopolistic nature of our business puts a power in our hands that we ought to exercise carefully. In operating the plant we are acting as trustees as well as employees. Our sense of fairness will often be put to the test, and it is better that we err in our judgment on the side of the water patron than make him feel that he had been treated unfairly, without tact or without due consideration.

Two complaints are the common experience and bane of operating officials, namely,

(a) High or excessive water bills
(b) Delinquent accounts which must be shut off to enforce payment

I assume, of course, that all progressive water systems are 100 percent metered. I hold no brief for the meter salesman, but how a water department can operate efficiently and economically when it does not measure its product or output is beyond comprehension.

In this respect the west is far in advance of the east and much to our advantage.

METER READING AND ADJUSTMENTS

The water meter is the cash register of the water department. Theoretically at least, the amount of water registered by the meter determines the amount the consumer has to pay. But there are often extenuating circumstances. As a police officer watching day and night to detect water wastage, the meter has no equal, and in Seattle we would long ago have required more pipe lines and storage facilities, had we not way back in 1908 adopted the policy of universal metered water service.

We read meters monthly and bill all services having 1 inch or larger meters, or where the bill runs over $5.00 per month, once a month. All other meters, although read monthly, are rendered quarterly.

We believe it to be good policy to read meters monthly because of the more frequent check which we obtain on a patron's water consumption. If something unusual or abnormal occurs in the meter reading, it is better to catch it within a month's time, rather than 3 months later. Again, many meters are stuck by sawdust, vegetable matter or even small fish getting into the meter. This causes estimated bills, which frequently are a source of annoyance both to the department and to the consumer. When we discover a high reading we immediately notify the owner or tenant and make a proper notation on our meter reading book. Almost always the owner promptly has his fixtures repaired for he knows that he is penalized in real money unless he does. It sometimes happens, however, that the leak cannot be detected becaust it is under a cement floor and gives no surface indication. Therefore, when the leak finally is discovered the owner feels that he is entitled to some consideration. Here we can display our judgment or discretion. If we follow the letter of the law the consumer is liable and we have it in our power to make him pay. But should we use this power in an arbitrary way? Should not the principle govern that when a consumer has used due diligence and every care and after exhausting all resources he is entitled to consideration and an adjustment made based on the usual amount of water consumed?

Another matter is the collection of delinquent accounts. How rigid should we be in the collection of water rates after they become delinquent?

In our state water rates are a lien against the premises, and we virtually have the property as security for the payment of water bills. But how about the owner that insists that the tenant shall pay the bill and that promptly?

Some cities, and particularly private utilities, use the device of allowing a discount of say 10 percent for payment on or before due date. In effect this is a severe penalty or increase in rate for a patron who may not be in a position to pay the bill just at due date.

Nevertheless it is a fact that with some few people enforcement only by shut off, will bring them into the office to pay the bills.

Our delinquent lists always contain the names of those chronically unwilling or unable to pay their water bills.

No large account in Seattle is shut off unless it is in arrears over 30 days, and, in case of residences, 90 days.

A second notice is in effect given to everyone, because the subsequent bill calls attention to the fact that the previous bill is delinquent and unpaid and therefore subject to discontinuance of service.

The writer has been in active charge of the commercial division of the water department in Seattle for over 20 years. In the good old days we were not so lenient with a delinquent patron, but our viewpoint is changing. We now give every consumer every possible chance, and readily grant extensions of time and credit, for we should place a higher value on good will.

PUBLICITY

One more thought and I shall close. What do we do with reference to advising our customers about the affairs of the water department. It is true, we get out annual reports, which contain a lot of tables, statistics and other information which very few read or have time to digest. How and by what means can we arouse the interest and sympathetic coöperation of the public in their own enterprise?

What are we doing to advise the younger generation about the enterprises which they in a few years will be called upon to operate and administer?

In Seattle the superintendent of water has a fine collection of slides, and moving picture equipment, that visualizes the work and activities of the department.

The public takes very kindly to this, which acts as a means to put them in close touch with the activities and work in progress.

As our communities grow and with them the utilities which are as necessary to their well being as the air they breathe, everything that we can do to make them realize the progress and expansion and growth of their public service enterprises, is a factor that should prove helpful and beneficial to all concerned.

WATER METER REGISTERING AND TESTING[1]

By George Read[2]

There is a difference of opinion among water works men as to how long a water meter should remain in service before testing. The writer has always contended that periodic testing of meters under ordinary conditions is not economical or necessary when they are read monthly, the consumption is carefully compared with former months (taking into consideration seasonal demand) and inspection is ordered when readings indicate a sudden or gradual falling off in registration.

In order to verify this contention, 900 meters that have been in continuous service from one to ten years were taken out at random and tested at the meter shop on the same rates of delivery as were used when they were new. After they were tested they were again put in service. The results of this testing appear in table 1.

When a meter is new the inside of the measuring chamber and the piston is clean and smooth. The amount of water that passes through the measuring chamber per gyration or oscillation of the piston is theoretically equal to the cubical contents of the measuring chamber minus the displacement of the piston. The number of piston gyrations or oscillations per cubic foot varies according to the size of the meter. A gear train with a fixed reduction and a set of change gears, which ratio can be changed, transmits the piston gyrations or oscillations to the register.

Over a considerable range of delivery the amount of water that passes through the measuring chamber per each gyration or oscillation of the piston remains practically constant, hence the piston gyrations or oscillations per cubic foot also remain practically constant. The ratio of the change gears to cause 100 per cent registration is determined by the number of piston gyrations or oscillations required to pass 1 cubic foot of water through the measuring chamber. All meters have a high peak registration flow. Meters that are geared to

[1] Presented before the California Section meeting, October 25, 1929.

[2] Meter and Service Superintendent, Department of Water and Power. Los Angeles, Calif.

record 100 per cent on ordinary rates of delivery will show an over-registration on these high peak registration deliveries because on these particular rates of delivery the amount of water passing through the measuring chamber per gyration or oscillation of the piston is slightly decreased, hence the piston gyrations or oscillations per cubic foot has been slightly increased and the change gears cannot automatically adjust themselves to this change. The reason for the over-registration on high peak registration flows is that the piston under these rates of delivery is nearer positive in displacement than other rates.

TABLE 1

Meter registration tests

LENGTH OF TIME IN SERVICE	METERS TESTED		AVERAGE PER CENT OF REGISTRATION			
			When installed		When removed	
	Number	Size	Fast flow	Slow flow	Fast flow	Slow flow
years		*inch*				
1	100	$\frac{5}{8}$ x $\frac{3}{4}$	99.55	100.37	100.52	101.36
2	100	$\frac{5}{8}$ x $\frac{3}{4}$	98.90	100.82	100.19	100.74
3	100	$\frac{5}{8}$ x $\frac{3}{4}$	99.38	100.38	100.81	101.49
4	100	$\frac{5}{8}$ x $\frac{3}{4}$	99.17	101.91	100.75	97.10
5	100	$\frac{5}{8}$ x $\frac{3}{4}$	99.32	100.56	101.04	99.90
6	100	$\frac{5}{8}$ x $\frac{3}{4}$	99.51	101.36	101.59	101.24
7	50	$\frac{5}{8}$ x $\frac{3}{4}$	99.36	101.14	101.66	95.46
8	50	$\frac{5}{8}$ x $\frac{3}{4}$	99.62	101.64	102.22	102.02
9	50	$\frac{5}{8}$ x $\frac{3}{4}$	99.98	100.03	100.56	97.94
10	50	$\frac{5}{8}$ x $\frac{3}{4}$	99.34	100.64	97.94	97.76
7	50	$\frac{3}{4}$ x 1	99.20	100.66	100.46	100.14
7	50	1	99.74	100.42	101.04	97.16
General average.....			99.43	100.84	100.71	99.34

Note: The fast flow for $\frac{5}{8}$ x $\frac{3}{4}$ inch meters was $1\frac{1}{2}$ cubic feet per minute. The fast flow for $\frac{3}{4}$ x 1 inch meters was 2 cubic feet per minute. The fast flow for 1 inch meters was 3 cubic feet per minute. The slow flow for all sizes was at the rate of 10 cubic feet per hour.

After a meter has been in service some time a slimy deposit occurs on the piston and on the inside walls of the measuring chamber. This deposit slightly reduces the amount of water passing through the measuring chamber per gyration or oscillation of the piston and consequently slightly increases the piston gyrations or oscillations of the piston per cubic foot. Since the change gears are not able to adjust

themselves automatically to these conditions a small over-registration occurs.

When testing a meter on variable rates of delivery there can always be found a very small flow that will pass through the measuring chamber without moving the piston. A slight increase of this flow may cause the piston to operate a little and so on until a flow is reached that will cause the piston to operate fully and show 100 per cent registration. Some meters being more sensitive than others record 100 per cent on smaller rates of delivery. The lack of sensibility may be due to a poor piston fit, a very tight stuffing box, piston control roller, or a dragging gear train, etc. Flows through meters exceeding their maximum rated capacity will cause an under-registration due to slippage caused by friction.

Oscillating or gyrating piston meters referred to are not absolutely positive in displacement because, if they were, there would not be any practical variation in the amount of water passing through the measuring chamber per gyration or oscillation of the piston. Water may be drawn through these types of meters in the $\frac{5}{8}$-inch sizes, under 30 pounds per square inch at the rate of one-half a cubic foot per minute without moving the piston. In fact, it is a good thing that they are not absolutely positive in displacement because if they were, when a meter stopped operating, the consumer would be cut off without warning which might be dangerous in many cases and also the Department would be kept hopping from place to place changing meters.

What has been said in regard to slight over-registration of meters due to high peak registration flows, etc., refers only to meters in the pink of condition. Water passes through the measuring chambers of meters at flows from a mere seep to the factories' rated greatest proper quantity and sometimes beyond this. If a test were made on all these variable flows the average registration on the bulk of the meters in service would be found to be under 100 per cent. In addition, when we consider the under-registration that occurs due to worn measuring chambers, pistons, gear trains, change gears and pistons warped by heat, no consumer need worry about being over charged. It is perfectly safe to say that when a properly geared meter is set and is finally removed from service on account of being inoperative, more water has passed through its measuring chamber than is recorded on its register.

When testing small meters in service by a test meter, the meter to

be tested should be temporarily removed from its setting to the surface of the ground and a piece of hose for flexibility should be used to connect its inlet side to the curb cock. This test meter should be connected to the meter to be tested with a piece of hose or pipe two or three feet long. A piece of hose or pipe should be connected to the outlet side of the test meter with a valve on its discharge end for flow regulation. If the lowest dial on the meter to be tested is 10 cubic feet that much, at the very least, should be drawn in making the test. Two or three rates of delivery should be used on which the test meter is known to record 100 per cent. After the meter is tested for accuracy it should be tested for sensibility. Meters larger than 1-inch

TABLE 2

LENGTH OF TIME IN SERVICE	NUMBER OF METERS TESTED	CONDITION OF LUBRICATION			PERCENTAGE		
		Good	Fair	Poor	Good	Fair	Poor
years							
1	100	100			100		
2	100	94	6		94	6	
3	100	91	9		91	9	
4	100	97	3		97	3	
5	100	68	21	11	68	21	11
6	100	90	10		90	10	
7	131	101	23	7	77	18	5
8	50	1	16	33	2	32	66

Note: Only 68 percent of the oiled trains that were in service for five years showed good lubrication, which I think was primarily due to too small an amount of lubricant in the beginning.

should be brought to the shop for testing purposes, in fact, it is better to do all meter testing at the meter shop.

OIL ENCLOSED GEAR TRAINS

Considerable thought by water works men is now being given to how long the oil in gear trains will last and of what benefit it is to the life of the train. As 781 out of the 900 meters that were removed for testing purposes contained gear trains running in oil, the condition of the oil in each of these gear trains was carefully examined and the result of such examination is shown in table 2.

The above oil enclosed gear trains were closely examined in regard to wear and were all found to be in very good condition. One

hundred of the meters taken out for testing purposes containing open type gear trains (non-oiled) were closely examined to determine difference in wear between the open type and the oil enclosed. The conditions of these open type trains are shown in table 3.

We have not determined as yet the advisability or economy of reoiling gear trains at set periods of time.

Table 1 showing the registration of meters that have been in service from one to ten years has proven that periodical testing of

TABLE 3

LENGTH OF TIME IN SERVICE	NUMBER OF GEAR TRAINS EXAMINED	CONDITION OF GEAR TRAIN				PERCENTAGE			
		Good	Fair	Poor	Badly worn	Good	Fair	Poor	Badly worn
years									
9	50	17	21		12	34	42		24
10	50	17	25	1	7	34	50	2	14

Note: Although these open type (non-oiled) trains were in service one to ten years longer than the oil enclosed trains the difference in condition plainly proves, without doubt, that the oiling materially prolongs the life of the train and also keeps the gear train sensitive for operation on small flows.

meters under ordinary conditions is unnecessary and uneconomical. Another factor, however, should be considered. On an average 10 per cent of the meters in service are removed annually due to wear, damage by hot water, broken registers, street work, enlargements, discontinuance of service, etc. About 41 per cent of the meters removed for not operating are due to being damaged by hot water. Of course, periodic testing will always find a few meters under-registering, but the cost of finding them will be far greater than the loss by under-registration.

CHANGING FROM A FLAT RATE TO A METER BASIS IN A MUNICIPAL PLANT[1]

By Alexander Orr[2]

On many occasions the writer of this article has listened to remarks made by fellow superintendents at our occasional meetings, to the effect that they wished that they might be able to change in their water departments from a flat to a meter rate schedule.

Engineers and superintendents generally recognize that the meter basis is the only practical business way to obtain revenue from the sales of their products. For some reason, however, their communities are opposed to such a change and many water departments still use the antiquated and cumbersome flat rate schedules.

Public utilities owned and operated by corporate or private interests universally sell their product on a measurement rate basis and are always in a position to know the exact relation between earnings and output or product for said earnings. On the other hand, municipally operated utilities selling their product on a flat rate basis never know the relation between these two items.

The writer will endeaver to outline the methods employed to bring about in the city water department of Gloversville, N. Y., the universal adoption of the meter rate basis and the steps which were taken to meet the opposition against such a change.

Gloversville has a population of about 23,000 and its principal industries are the manufacture of gloves and the production of leathers of all kinds.

Its water supply system is municipally owned and is a gravity system obtaining its supply from mountain streams in the foothills of the Adirondack mountains. It has a reserve capacity in its storage works of approximately 400,000,000 gallons.

The water department of the city is under the charge and control of a board of water commissioners of five members who are elected by the city at large for a term of four years. Its duties and rights are

[1] Presented before the New York Section meeting, April 25, 1930.

[2] Superintendent, Board of Water Commissioners, Gloversville, N. Y.

prescribed by a special act of State Legislature creating the said board.

When the writer became connected with the water department in 1899, the department was facing an acute shortage of water, the storage capacity of the system at that time amounted to approximately 18,000,000 gallons and the end of this reserve supply was in sight. Only the early appearance of a rainy season saved the city from serious consequences.

About this same time a radical change had been brought about by the leather manufacturers in the methods and processes of tanning and dressing leather. Prior thereto the time consumed in producing finished leather from the raw stock was from 2 to 18 months. New processes of tanning and dressing were perfected so that at the present time the same leathers are produced in from 6 to 14 days and of a much finer quality in every respect.

The city water is very clear and soft. The total hardness runs from 22 to 30 and is claimed by leather dressers to be the finest water for leather dressing purposes in the world. Due to its softness and relative freedom from minerals in solution the tanners are able to produce leathers of the finest texture and finished in the softest shades of all colors.

This change in the methods of dressing leather increased very greatly the amount of water used by the tanners and in order to preserve the industry to our city it was immediately necessary that the board of water commissioners take steps to provide the necessary additional supply.

At this time the city had already taken over and was using all the available sources of supply and the only method left to increase the water supply was the development of storage works on one or more of the streams supplying the city. The Board immediately made plans and took steps to carry out a building program looking to the creation of additional storage capacities and enlargement of city mains to make such additional supplies available.

At the same time the Board was strongly impressed with the fact that steps should also be taken to prevent the loss by waste of such supplies and that the daily consumption should be reduced as nearly as possible to legitimate and proper uses.

House to house inspections had been periodically made for some years past and the tabulated results from such inspections always revealed that from 50 to 75 per cent of all service pipes had one or

more leaky fixtures connected therewith. Orders to repair forthwith served on the owners of the properties affected would bring about some immediate response, but generally there was a neglect in repairing the defective fixtures and the Board soon became convinced that the house to house inspection was of little use and decided that the only way to conserve the water supply was to adopt the meter system.

At this time the Board had in effect a classified meter service which compelled all service pipes leading to manufacturing plants, hotels, livery stables, laundries and business blocks to be metered. This classified list had been in effect for some years and about three hundred meters were in use.

In arriving at the conclusion as stated the Board realized that there would be serious opposition from certain interests against universal meterage as soon as their plans became generally known. As one step to combat this opposition they decided to buy 100 meters, to be placed on domestic services where it was thought the effect would do the most good for the plan. Very often some property owner having a small family would object to the water tax he was paying under the flat rate as compared with some neighbor with a large family, who was paying the same rate. Here it was suggested to him that he have a meter placed on his service pipe and thus pay for his actual use. Instances of this kind, together with applications for meters from others who were interested in the proposition, soon used up the hundred meters and the Board was obliged to buy more to meet such requests.

The next move was to add to the classified list all service pipes leading to boarding and lodging houses.

A further study of the tabulated results of house to house inspections showed that one particular type of fixture, the hopper closet, was a serious waster of water and that there was about five hundred of these in use. The Board immediately ordered meters placed on all service pipes leading to properties having such closets.

The Board then passed a resolution and ordinance requiring all new and all re-placed service pipes metered. This resulted in 100 to 120 additional meters each year.

In 1907, the Board, after a study of the results of the meter installations as heretofore cited, enacted and passed a general ordinance requiring all service pipes connected to the water supply system of the city to be metered, that all water supplied to said service pipes be at the existing schedule of meter rates, and that the meters

necessary to carry out the foregoing ordinance be bought and installed as fast as the finances of the department would allow.

This action started the fireworks. Letters and newspaper articles appeared in the daily press from the opposition. These articles were met by articles written and published by several consumers who had had for some time meters on their service pipes and gave encouragement to the Board to proceed along the lines settled on. Some of the articles from the opposition were answered by the Board giving a general description of the waste of water on specified premises and described in such a way that everybody knew who owned such properties without naming the specific objector. One such objector who made the biggest howl came out in the press with a letter stating that he had investigated the meter proposition in reference to a number of cities and that in all of the cities mentioned the adoption of meters would not be tolerated. The writer immediately got in touch with the water departments of the cities referred to and immediately received replies that the meter system had been adopted and that meters were required on all service pipes and that those not yet metered were gradually being metered. This objector's original letter was then again published together with the replies received by the writer from the cities referred to and no further opposition came from this objector's camp. The last wail of the opposition was to conduct a voting contest on the question of adopting meters in the daily press by means of a coupon to be filled out and mailed. Of course, these coupons were filled out and mailed in by everybody no matter whether they were city or rural residents. However, before the final count was made (if it ever was) the city water works system was 70 percent metered and water consumers were still asking for meters on their service pipes of their own volition.

The final work of metering unmetered services was carried out by taking one street in each of the six wards and ordering and placing meters on service pipes not already metered. This method was repeated from time to time until all the city was covered. On January 1, 1913 the Water Board was able to report the city 100 percent metered.

FINANCIAL IMPLICATIONS OF METER SCHEDULE

The schedule of meter rates in force up to 1909 was based on an average daily consumption and was in terms of gallons. This schedule was found to be in many cases unfair and cumbersome and in 1909 the following schedule was adopted:

	cents per 100 cubic feet
For the first 5000 cu. ft.	12
For the next 5000 cu. ft.	10
For the next 5000 cu. ft.	8
For the next 5000 cu. ft.	6
For the next 5000 cu. ft.	4
For the next 5000 cu. ft.	3
For all over 30000 cu. ft.	2½

Minimum charge per meter for 6 months..... $2.00

The above schedule was in effect until 1917 when the last two items of the schedule were eliminated making all water used over 25,000 cubic feet at 3½ cents per 100 cubic feet.

In 1899 when the writer became connected with the department he found some three hundred meters already installed as stated heretofore. They were of some twelve different makes of meter.

Several of these meters were now coming in for repairs and adjustments and I soon came to the conclusion that the cost of maintaining a supply of repair parts for all the different makes of meters would be unwarranted. I began to eliminate and finally cut down and standardized on one make of meter. The costs of repairs and maintaining stock of parts was accordingly reduced.

Looking to the proper care and maintenance of these meters one of our men was sent to the factory and given a comprehensive schooling in the assembly, testing and repair shops of the factory. On his return he was placed in charge of all mechanical and repair work connected with the meter department.

This man is sent at regular intervals to the factory for instruction in order to keep abreast of such work and we find that this procedure saves us large amounts in the cost of upkeep of our meters.

Our meter shop is equipped with proper tools, testing bench and stock of meter repair parts.

As to the effect of installing meters on domestic services we find that generally 80 percent of such consumers saved money or broke fairly even as compared with the old flat rates. The other 20 percent paid for what they used and wasted and more than made up for the loss due to the savings of the other 80 percent. Any suggestion today in the City of Gloversville to return domestic consumers to a flat rate schedule would not be tolerated by the majority of such consumers.

As to the effects on the earnings of the department our books show that during the three years that the work of installing meters was at

its high pitch the earnings fell off about five thousand dollars each year. This is accounted for by two reasons, first, the savings made by consumers and, second, that under the flat rate schedule we collected water taxes for six months in advance, and where a meter was set we only received six months revenue for the current year, from that consumer.

Under the former flat rate system water taxes were collected from the whole city every six months in May and November. As the number of meters set began to increase it soon became evident that the billing work, etc., connected with meter accounts would make this method cumbersome and impracticable. The city was, therefore, divided into three collection districts, each district collected every six months and thus giving a collection in the office every two months. This change simplified the work and keeps a steady stream of work going through the office and a steady stream of money coming in. The entire work of figuring, billing and collecting water taxes together with all other clerical work of the department is done by 2 people.

The entire work of reading, setting, replacing and repairing of all meters is done by 3 men. At the present time we have 5230 meters installed, all read four times a year, twice for collection and twice for checking.

In conclusion, the writer from his experience believes that all communities are alike to a great extent, the proportion of fair minded tax payers is in a majority, the opposition to be met against a meter rate basis is due largely to ignorance on the subject and a small amount of education will swing this opposition to support. There will always be opposition, however, from certain elements who know that under the meter basis they will have to walk up and settle in full for what they are receiving to a great extent free under the flat rate schedule.

In Gloversville today and for several years past we do not know or fear a water shortage. We are satisfied that the universal adoption of a meter basis in our city has been a great factor in conserving our supply and bringing about this condition.

METER MAINTENANCE AND TESTING IN A SMALL TOWN[1]

By A. H. Labsap[2]

Longview, the industrial town, built by the Long-Bell Lumber Company, has all its utilities placed in the alleys. These are uniformly 20 feet in width, except in a zoned wholesale district where they are 40 to 45 feet wide, giving access to two railroad tracks. In this case, the water mains are laid in the parking.

Placing the mains in the alleys is an advantage when it is considered that miles of pavement were laid before a building was built. Even now, this condition obtains to a limited extent, and so far no pavement has had to be torn up because of water services. However, there are several distinct disadvantages to having the mains in the alleys. On long blocks in the business districts it is manifestly impossible to have hydrants in the centers of the blocks, since no easements from the alley to the street on private property can be secured. At such times as the town becomes built up and more hydrants are required, it will be necessary to run the hydrant leads from the feeder mains of the gridiron system. This will entail great expense and, because of the long leads, will increase the friction.

The greatest problem, however, with mains in the alleys, is that of water maintenance. Lots are generally 50 feet in width and in the average case have a 20-foot garage and 15-foot woodshed on or close to the lot line. This leaves a 15-foot space in which to put the service, but as this throws the meter out of line with the house plumbing, the consumer complains because of additional cost to himself.

The service is placed wherever the consumer wishes, provided the meter is protected. New water service orders received in the morning are filled in the afternoon. Those received in the afternoon are filled the following morning. When a customer applies for service, he signs an agreement stating he will comply with the regulations of the company. This agreement states that the liability of

[1] Presented before the Pacific Northwest Section meeting, April 25, 1930.

[2] Superintendent, Water Department, Longview, Wash.

the company stops at the meter. In practice, however, this is not the case. The company, in all cases of excessive water consumption checks the piping and plumbing of the consumer and advises him as to the cause of such excess.

A water service order is made out showing name, address, class and size of service, whether main is to be tapped or not, etc. Space is left for a meter record which when filled in shows the company and serial number, size, make, and reading. At the bottom is a small map showing several blocks, lots and streets on which the serviceman locates the service by measurement, when the service is completed. This is transferred in the office on to a 1 to 40 scale map.

Meters, when they are received from the manufacturer, are tested, stamped with the company number and sealed. A small piece of thin, transparent celluloid is inserted between the register figures and the top plate of the register. This keeps the figures on the dials free from moisture when the meter is in use, the figures barely touching the celluloid. To determine the effect the celluloid would leave on the figures, whether they would be erased or not, and also as to whether registration would be decreased, tests were made. About 40,000 cubic feet were run through a new meter. No wear on the figures could be noticed. Twenty-four hour tests were made on a meter equipped with the celluloid and one not so equipped. The rate of flow did not vary between the two.

Copper tubing has been used for service pipe for the past two years. Meters are placed one foot inside the consumers property line. Each meter has a stop cock on the company side and test tee on the consumers side. It is protected with the ordinary concrete meter box used on the Pacific Coast. Inasmuch as these are not long enough to cover the stop cock, meter, and test tee, the latter is buried and the meter is disconnected when field tests are necessary. It is in the protection of the meter, that the greatest problem arises. There is no protecting curb. There are no back fences except in a few instances. Garages and woodsheds do mark the lines in some sections and afford protection when the meter can be placed between them. Concrete boxes withstand the weight of light automobiles, but trucks crush them, or, if the ground is soft, drive them into the ground, breaking the meter connection.

So far, home made wooden boxes have given the best results, but they are unsightly and slow up meter reading. Placing the meters further back on the consumer's premises bring objections from the

householders. We have reached no solution of the problem. About 15 per cent of meter boxes in use are replaced each year. Great trouble has been experienced from moles burrowing along pipe and filling the boxes, sometimes completely covering the meters. Dirt works into the registers and they stop registering. Placing a cedar board the size of the meter box underneath the meter, has stopped this however.

The Department of Public Works of Washington requires that meters be tested as follows:

1 inch or less, at least once every five years.
1¼, 1½ and 2 inches, at least once every five years.
3 inches, at least every three years.
4 inches, at least every two years.

The above applies to utilities only. In compliance with these regulations which were adopted as of January 1, 1928, all water meters in Longview that had been in use five years, except a few of the largest sizes, were tested. Testing commenced in June, 1928. At the present time, there are no meters except those 3- and 4-inch in size which have not been tested. This program will be continued as the five year or less period for each new meter is reached.

Before commencing to test the meters, the Department of Public Works was requested to check and seal the meter scales. Two portable field meters were then tested and retested after each 100 meters were tested. Most of the meters were tested in the field, the shop meter tester beng used to test new meters. Before testing, meters were thoroughly cleaned, dirt, and grit being removed from registers, and minor repairs, such as replacement of screws, glasses, and top covers, were made. Broken meter boxes were replaced and the earth tamped around them.

The Department of Public Works recommends that all meters be tested at three rates of flow, and requires that those larger than 1-inch be tested at three or more rates.

It publishes a table showing the allowable range test flow and a recommended test rate flow. At Longview, where the average pressure maintained is between 95 and 100 pounds per square inch, it was found that by using orifices of ½-, ¼-, and ⅛-inch, these rates were most nearly attained. Five cubic feet of water at each rate of flow were run through each meter. The average of the test at the three rates of flow is taken as the percentage of correctness of the meter.

Less than 10 per cent of all meters tested were in error more than 2 per cent, using the ½-inch orifice. Since a very large percentage of water used is measured at this rate of flow, it would seem, in determining the average accuracy of meters, a weighted mean should be used rather than the average of the algebraic sum. The pressure being equal, the flow varies as the square root of the fifth power of the diameter. Using these figures in inverse ratio as the weight to be applied, they are roughly for Longview, 1, 6, and 30. By this method a great many meters which are within the limits as determined by actual use, but not by test, would not be rejected or rather it would not be necessary to change gears to correct inaccuracies.

TABLE 1

Cost data on meter maintenance

	1927	1928	1929
Inspecting and testing meters	$165.00	$1057.00	$337.00
Repairs to meters	828.00	2022.00	1028.00
Average number of cubic feet used per month per meter	1128	1163	1250
Per cent of water pumped that was sold	69.3	78.2	82.8
Per cent of water pumped used in operation	6.1	5.8	5.1
Per cent of water pumped unaccounted for	24.6	16.0	12.1
Per capita consumption—cu. ft. pumped	10.96	10.96	10.91
Per capita consumption—cu. ft. sold	7.63	8.59	8.97

Three different makes of meters are in use in Longview. Of the first 1400 installed, 158 or 12 per cent had to be adjusted to conform to the Departments new regulations. Until January 1, 1927, none of these had been tested before installation. Of one make of meter, 92 out of 288 had to be adjusted, of another, 48 out of 510, and of the third, 18 out of about 600. These comprise all the meters in use 5 years or longer. In all, 2200 of a total of 2700 have been tested.

The cost of repair parts to meters in service five years or longer has been 20 cents per meter since 1927 or a yearly cost per meter of about 7 cents. No labor is included in this. In studying the causes of damage to meters, it is found that dirt working into the registers and change gears causes the greatest trouble. One third of one per cent of the 2700 meters in use had to have new registers. Replacement of three gear trains only had been necessary. These were ⅝- by ¾-inch meters used with ice machines and each had registered more than

one million cubic feet. During the recent very cold spell, when the thermometer registered as low as 20 degrees below, it was necessary to replace five frost proof bottoms. This is a remarkably low number since the meters are placed from 12 to 16 inches below the ground, and the frost penetrated in some locations to a depth of 16 inches.

The average cost of testing each meter was about 75 cents. The labor cost of cleaning and of making repairs, while the testing was in progress, is included in this figure.

Table 1 covering the past three years shows the cost of inspecting and testing meters, cost of meter repairs, together with their relation to the per cent of water sold, water unaccounted for, etc.

While the cost chargeable to meters has been large, it has resulted in part in reducing the water unaccounted for from 24.6 to 12.1 per cent. All of this cannot be credited, however, to metering and care of meters. At the same time meters were being overhauled, an intensive campaign against leaks was carried on, which aided in reducing the unaccounted for water. Only 13.5 per cent of all meters in use at the end of five years under registered at all, and practically all of these did not exceed the 2 per cent limit allowed by the state. Less than 0.5 per cent of all new meters received since 1927 underregister when tested new.

CERTIFYING WATER SUPPLIES FOR INTERSTATE CARRIER USE[1]

By R. E. Tarbett[2]

The Interstate Quarantine Regulations state "Water provided by any person, firm, or corporation for drinking or culinary purposes on any car, vessel or other conveyance while engaged in interstate traffic shall be from a source which is approved by the Surgeon General of the United States Public Health Service as producing water of satisfactory sanitary quality and safety."

The law upon which these regulations are based was enacted by Congress in 1893. The title of the act is "An Act Granting Additional Quarantine Powers and Imposing Additional Duties upon the Marine Hospital Service" (Now the Public Health Service).

Section III of this Act has to do with coöperation between the federal government and state and local health authorities in the prevention of the introduction of disease into the United States from foreign countries and into one state or territory or the District of Columbia from another state or territory or the District of Columbia. The Secretary of the Treasury is instructed by the Act to "Make such additional rules and regulations as are necessary to prevent the introduction of such diseases . . . . and when such rules and regulations have been made they shall be promulgated by the Secretary of the Treasury and enforced by the sanitary authorities of the states and municipalities, where the State and municipal health authorities will undertake to execute and enforce them."

When this law was passed it was no doubt intended to establish primarily the machinery whereby the spread of such diseases as yellow fever, cholera and small pox might be checked. However, the Act used the all-inclusive term "contagious and infectious diseases" and thereby did not limit its effectiveness to those diseases known

[1] Presented before the Indiana Section, March 21, 1930, before the Florida Section, April 10, 1930 and before the Southeastern Section meetings, April 16, 1930.

[2] Sanitary Engineer, United States Public Health Service, Washington, D. C.

at that time to be communicable. Little attention was given other communicable diseases, typhoid in particular, until after the establishment of the Hygienic Laboratory in 1902 and even then field work was limited until the reorganization of the Service in 1912. The need of some federal control over drinking water supplied by interstate carriers first made itself evident on the Great Lakes vessels due in part to typhoid outbreaks among passengers and the high typhoid incidence among seamen treated at the Service hospitals.

The first record of the Federal Government taking an interest in the question of water supply was in 1896 when a bill was introduced in Congress calling for an investigation of the pollution of water supplies. In the same year the Marine Hospital Service attempted, through questionnaires, to obtain information relative to public water supplies.

The beginning of Federal control over the drinking and culinary water furnished on common carriers as well as the manner in which this water is handled by the carrier was in 1912. In that year the Interstate Quarantine Regulations were amended so as to require that all water provided for drinking and culinary purposes by common carriers should be certified by the state or municipal health authority within whose jurisdiction the supply was obtained as incapable of conveying disease. These amendments also included provisions relating to common drinking cups, towels, ice, water coolers and the like. At this time definite instructions were issued to the carriers relative to certification. Under this procedure the carriers obtained from the local health officers or the state boards of health certificates covering the sources and quality of water used, and forwarded these certificates to the Surgeon General.

1914 TREASURY DEPARTMENT STANDARD

In order that there might be standards by which to judge the safety of the water supplies, a Commission was appointed to establish such standards. This Commission made its report in 1914. In making the report the Commission confined itself to recommendations for a bacteriological standard. It realized that the results of any bacterial or chemical examination of water should always be correlated with a knowledge of the source, treatment, storage, distribution, etc., if a just estimate of the sanitary quality was to be made. At that time, however, first hand authoritative information regarding source, etc., was quite largely unprocurable. It may be of interest to note that

at that time, 1914, there were but twelve State Departments of Health in which an engineering division had been established and only fourteen states interested themselves to any extent in the question of water supplies.

Since only bacteriological standards were considered these were made somewhat more rigid than would have been the case had all features been taken into consideration. The Commission made it plain in its report that the Standards applied only to water furnished by common carriers and were not to be considered as standards for water supplies generally. Never the less, these standards were recognized notwithstanding the Commission's recommendations. They caused considerable comment since at that time few water treatment plants were consistently meeting them. As will be recalled, they required that the total number of bacteria developing on agar at 37°C. in 24 hours should not exceed 100 per cubic centimeter and that not more than one out of five 10 cubic centimeter portions of any sample should show the presence of the B. coli group.

From 1912 to 1919 the Regulations were changed and amended frequently to keep pace with developments. Throughout this period of change, however, certification rested entirely with the state and municipal health authorities, or where such authorities failed to act, with officers of the Public Health Service; except, that certification of vessel water supplies taken from overboard sources and treated on board was entirely under the control of the Public Health Service as at present.

The present method of investigation, recommendation and certification of water supplies furnished interstate carriers was developed in 1919 in coöperation with the state health authorities of the various states. Under the new arrangement the state health authorities were to investigate and report on the sources of water and were to make such recommendations as to certification as they deemed proper. The certificates based on these recommendations were to be issued by the Surgeon General. Where engineering services were not available in the states, assistance was to be given by the Public Health Service through assignment of engineers for limited periods of time.

The development of engineering divisions in the various state departments of health together with the assistance that the Public Health Service could render made it possible to include in the investigations of a water supply all the features that are necessary, namely, the sanitary survey of the source, treatment, distribution system, and the

like, as well as the physical, chemical and bacteriological conditions of the water. While the bacteriological standards promulgated in 1914 were still in force these alone were not used as a criterion but as one step in determining the probable safety of the supply.

In changing the method of certifying the supplies, three types of certificates were arranged for: (1) a full certificate without reservations, covering a supply which met the requirements in every way; (2) a provisional certificate covering a supply which could not be considered as warranting a full certificate due to undesirable features which constitute a potential danger; and (3) a certificate prohibiting the use of the water.

1925 TREASURY DEPARTMENT STANDARDS

With these changes in the method of certification it became necessary to amend and revise the existing standards and in 1922 an advisory committee was appointed for this purpose. With the development of state health departments and of engineering divisions in these departments, there then being thirty-six state health departments with engineering divisions, the Committee was able to consider standards from all angles and not from the very narrow one of bacteriological purity alone.

The present standards were promulgated in 1925 and in the promulgation it was stated that: "These Standards are adapted for use in administration of the Interstate Quarantine Regulations as they relate to drinking and culinary water supplied by common carriers in interstate commerce. They are made especially applicable to the particular purpose and are not proposed for more general application." Again, notwithstanding the fact that these standards were to apply only to such water supplies as were used by interstate carriers, they have been generally adopted as standards by which all water supplies in the United States are judged.

In brief these Standards are as follows: (1) The water supply shall be obtained from a source free from pollution; or obtained from a source adequately protected by natural agencies from the effects of pollution; or adequately protected by artificial treatment.

(2) The water supply system, including reservoirs, pipe lines, wells, pumping equipment, purification works, distributing reservoirs, mains and service pipes, shall be free from sanitary defects.

(3) The bacteriological quality of the water shall conform to the following: (1) Of all standard 10 cubic centimeter portions examined

in accordance with the procedure outlined in the Standard Methods of Water Analysis, not more than 10 percent shall show the presence of organisms of the B. coli group; (2) Occasionally three or more of the five 10 cubic centimeter portions constituting a single standard sample may show the presence of B. coli. This shall not be allowable if it occurs in more than (*a*) five percent of the standard samples when twenty or more samples have been examined; (*b*) one standard sample when less than twenty samples have been examined.

(4) The water should be clear, colorless, odorless, and pleasant to the taste and should not contain an excessive amount of soluble mineral substances nor of any chemicals employed in treatment.

In recommending these Standards the Committee stated: "The Committee, therefore, considers it preferable to recommend that in actual practice the bacteriological standard be applied as are other requirements, with some latitude; in other words, that supplies which, on rigid inspection, are found to be satisfactory in other respects but fail to meet the bacteriological standard may be accepted in the discretion of the certifying authority."

It will be seen that in judging the probable safety of a supply the sanitary survey is the most important criterion upon which this safety is based, the bacteriological results as well as the chemical being an integral part of such survey.

The Committee outlined in some detail items to be considered in making the sanitary survey and since it is intended to discuss some of these items more fully the bacteriological and chemical standards will be briefly presented first.

Since the bacteriological results are to be considered in connection with the survey and as a check on that survey, it is essential that the laboratory procedure be uniform in all states and that the methods outlined in the Standards be followed without change.

The question arises as to the frequency with which examinations of water should be made if the quality of a water is to be properly judged. This question can be answered only when one has knowledge of the source of supply and the manner in which it is safeguarded. A deep well supply under the best conditions would need but very few examinations in a year where a badly polluted surface supply treated in a modern treatment plant should have daily examinations made by a competent operator in whom the state department of health has confidence.

Since the state health officer, or, perhaps more properly the state

sanitary engineer, is responsible for the recommendations made to the Surgeon General relative to certification, it is for him to decide as to the requisite number of examinations for any definite period of time. Strict compliance with the bacteriological standards may not be necessary in recommending full certification. On the other hand, a supply meeting the bacteriological requirements may not necessarily be recommended for a full certificate where the survey indicates undesirable features which may introduce a potential danger.

No definite standards are set for the physical and chemical characteristics of the water. The Committee sets forth in the appendix to the report certain maximum values ordinarily allowable in water supplies, but water that is generally acceptable in appearance, taste, and odor will be considered as satisfactory even though some of the set limitations are exceeded.

In making the sanitary survey of a water supply the investigator should make every effort to discover the existence of those undesirable features that may constitute a potential danger since such features generally warrant recommending provisional certification. This type of certificate does not prohibit the use of water but brings to the attention of the carrier the fact that certain sanitary defects exist and that failure to correct these may bring about the placing of the supply in the prohibited class.

SANITARY DEFECTS

It may be well to consider some of the undesirable features of a water supply the existence of which warrant a recommendation for other than full certification.

The sanitary defects in connection with ground water supplies require little comment as they are familiar to all. Where wells are located in the built up sections of a community greater care must be exercised in making the survey if one would be assured that actual or potential dangers do not exist. In these cases much more frequent bacteriological examinations would seem desirable than in the case of similar supplies located in areas less liable to ground water pollution. Unless such wells may be classed as deep wells, taking their water from below the first water bearing stratum, it would seem desirable that chlorination be provided. Supplies taken from cavernous limestone formations should not be considered as meeting the standards unless chlorinated, regardless of what the bacteriological examinations from time to time may disclose.

In general, surface water supplies, unfiltered, should not be considered as meeting the standards unless disinfected before use notwithstanding the character of the watershed or of the control over it. In certain cases such supplies might, without treatment, warrant a full certification, but, in general, well controlled surface supplies with inpounding reservoirs would not warrant better than a provisional certification unless proper disinfection is carried out. Proper disinfection implies adequate equipment to insure against any lapse in treatment and effective treatment checked by ortho-tolidin tests. Unfiltered surface supplies taken from flowing streams traveling inhabited regions should rarely be given full certification even when disinfection is carried on.

Judging the probable safety of filtered surface water supplies, particularly where the raw water is heavily polluted, requires considerable study of the source, the physical plant and the operation together with a sufficient number of bacteriological results of both the raw and treated water. Streeter's[3] studies on loading of filter plants have shown the limits of pollution, as determined by the B. coli index, beyond which filtration plants may not be expected to meet the bacteriological standards at all times. These limits should be borne in mind and when they are exceeded it would not be expected that the supply could receive a full certification and at times perhaps even a provisional certification would not be warranted.

Emergency intakes and by-passes which are not protected in such manner as to prevent any possible entrance of untreated water to the distribution system would be sufficient to warrant a provisional certification. In all cases of emergency intakes and by-passes, even though properly safeguarded, arrangements should be made whereby the water may be promptly and adequately disinfected in case such intakes or by-passes are used.

Proper operation of the treatment plant is extremely important. Chlorinating devices should be such that no possible interruption in the application of the disinfectant can take place. This generally requires duplicate apparatus although in some cases the carrying of duplicate parts will suffice. In all cases residual chlorine tests should be made and the dosage maintained so as to give the pre-determined residual chlorine. Failure to carry on residual chlorine tests properly would warrant a provisional certification on an otherwise satisfactory plant.

[3] Public Health Bulletins 172 and 193. Studies of the Efficiency of Water Purification Processes I, II, III, IV. H. W. Streeter.

A sanitary defect in a pumping plant, in addition to the usual defects, is inadequate pumping capacity and this should be considered in a survey of a supply.

The two sanitary defects in the distribution system which are perhaps the most troublesome are improperly protected distributing reservoirs and cross connections with other supplies.

Uncovered distributing reservoirs located within or adjacent to built up sections of a community are subjected to pollution from bird droppings, dust and to trespassing. A considerable part of this pollution while increasing the B. coli content of the water is probably not of a dangerous nature in so far as communicable disease transmission is concerned. However, the presence of organisms of the B. coli group in water is our one index of possible dangerous pollution of that water. If, therefore, the B. coli content of the water is increased due to the introduction of non-dangerous pollution, we destroy the index by which we are to judge the probable safety of the supply. It would seem that in general the covering of distributing reservoirs is desirable. Where a supply is obtained from ground water sources, covering of reservoirs is doubly desirable in order to prevent algae growths with resultant tastes and odors in the water. In many cases it is entirely within reason to recommend provisional certification where distributing reservoirs are not properly protected and, perhaps, in exceptional cases to recommend that the supply be prohibited for use.

The question of cross connections is apparently with us always notwithstanding the fact that the majority of the states have adopted regulations which, if enforced, would properly control this problem.

The American Water Works Association, the New England Water Works Association and the Conference of State Sanitary Engineers have studied the problem and have reported thereon with recommendations. It would seem that little more need be said.

In issuing certificates covering supplies used by interstate carriers only provisional certificates have been issued where it has been known that uncontrolled cross connections, particularly with polluted supplies, existed. Where reports from states make no mention of cross connections it has been assumed that they did not exist or that they were properly safeguarded.

In order that there might be no inconsistency in the issuing of certificates, instructions were sent to the various state health departments under date of January 11, 1930, relative to reporting on supplies where cross connections exist. It was not the intention that

supplies where such existed be given a prohibitive certificate unless conditions were such as to make the supply dangerous for use. It was intended, however, that where uncontrolled cross connections exist such supplies should not be recommended for full certification. It is not intended that the number of water supplies available for the carriers use be reduced or that the carriers be subjected to additional trouble in obtaining satisfactory supplies, although it is possible that certain supplies which have heretofor received full certification may under this ruling be placed in the provisional class.

The ruling of the Surgeon General refers to cross connections with other supplies and was not intended to include cross connections with swimming pools, those due to faulty design of plumbing and other fixtures, use of water in closed systems for cooling purposes and the like.

The Committee on Standards listed as a sanitary defect the existence of cross connections between primary supply and secondary supply of unsafe quality, for fire protection, emergency and industrial supply. The term "unsafe quality" must app'y to all secondary supplies from whatever source, concerning which nothing definite is known relative to quality.

Cross connections with other potable public supplies, or with other potable supplies regularly examined by those in charge of the supply to which cross connected are considered as properly protected. Cross connections, however, with secondary supplies, whether from surface or ground sources, and which may or may not be potable, must be (1) properly equipped with modern protective devices approved by the state department of health and installed and operated under that department or under the water department with full approval of the state department; or (2) where such supplies are of a potable nature routine laboratory examinations must be made at such intervals as the state department deems proper. Where cross connections exist and a water department is not maintaining necessary control through inspections, laboratory examinations, and the like to the full satisfaction of the state health department, that department would not be warranted in recommending a full certificate for the supply. Where violations of the state regulations relative to cross connections exist it would not be expected that such supplies would be recommended for a full certificate.

In investigating and reporting on the probable safety of a water supply it is realized that no set procedure may be followed. The

reliability of the data obtained as well as the interpretation of that data depend largely upon the competency of the investigator and upon his experience in the field of water supply.

We have no definite yard stick by which to measure the results that have been attained during the ten years the present certification procedure has been in force. It is believed, however, that the advances in the art of water treatment, the improvements in public water supplies and the increased efficiency of state control over public water supplies has been due, in part at least, to the establishment of standards and to the requirement that water supplies furnishing water for drinking and culinary purposes on interstate carriers shall comply with these standards.

It is interesting to note that in 1920 only 42 percent of the supplies listed by the carriers were certified whereas at present this percentage is over 80 and those supplies not recommended for certification in any one year are for the most part satisfactory.

During the ten year period there has been a considerable tightening up in the certification procedure but during that period considerable advance has been made in the art of water treatment hence no great hardship is imposed in requiring that all water furnished to interstate carriers for drinking and culinary purposes meet the standards as at present in force.

DISCUSSION

H. E. JORDAN:[4] Mr. Tarbett's paper is a very useful summary of the development of interest in and control of water supplies by the United States Public Health Service.

In a discussion revolving about the present Treasury Standard, reference may be made not only to the sections cited by Mr. Tarbett but also to the section of the appraisal committee report reading as follows:

"It is recognized that the definite terms of bacteriological quality in which this standard is expressed represent only agreement as to safety, and not as to limiting values beyond which demonstrable or even presumptive danger lies. Between the point on which the committee is in agreement as to the assured safety of water supplies and the point at which agreement could be reached as to their dangerous quality is a wide zone. Within this zone lie many water supplies which, if considered in the light of available evidence from all angles,

[4] Indianapolis Water Company, Indianapolis, Ind.

are believed to be as safe as other supplies which conform to all the bacteriological requirements."

One acquainted with the discussions that went on during the preparation of the report is aware that the limiting figures of the bacteriological standard were carefully referred to performance data of well operated American water palnts.

It cannot be too emphatically stated that, while an individual upward deviation from the limiting figure would be regarded by any member of the committee as undesirable, it would not be regarded as evidence of danger unless associated with definitely demonstrable deviations in the plant structures, operating methods or stream loading. There has been a certain tendency toward "post hoc, propter hoc" reasoning in this matter. One finds references in reports on waters indicating a tendency to label as unsafe or unsatisfactory samples deviating above the standard point.

One state classes only as "Fair" water supplies conforming to the Treasury Standard and sets up two higher classifications labelled "Good" and "Excellent." This tendency cannot be viewed with equanimity. It smacks of swivel chair engineering and is not based upon a broad view of the public health field and of the relative values of various health-guarding measures.

Certainly the density of B. coli just without the Treasury limits cannot be regarded "per se" as dangerous. How, then, can one justify the acceptance as satisfactory market milk whose Coli density ranges from 100 to 1000 per 100 cc. instead of only 1 per 100 cc. which some have interpreted as allowed in water by the Treasury Standard? Does not the life history of Coli in the milk environment have a significance of danger? Is there really not a tendency to over-emphasize the relation of water to public health and to set up standards for it which if paralleled in other comparable lines would revolutionize production methods? There is reasonable evidence that major emphasis can now be well placed upon the less popular matter of housing and domestic sanitation with great benefit to community health.

Does the health program seem well balanced in a community having a public water supply continuously certifiable and a model sewage disposal plant well operated, but where hundreds of shallow private wells still exist alongside (often very closely) the product of the "specialist's" art? What real effect will be produced in a community by improving the quality of the water supply to a limiting aver-

age of 1 percent of the samples positive if there is no control of the recovered typhoid patients and no check to see if they are carriers?

The present terms of the Treasury Standard for water, if met, amply protect the user. Other lines of health activity should catch up.

One views with approbation the order for provisional certification only of those supplies connected to doubtful private supplies. It will help to reduce their number. One misconception concerning cross connections can easily be cleared up. No alert water plant manager or superintendent wishes to maintain them. They are bad from a business viewpoint. Each private supply cuts potential revenue. Every private supply eliminated brings business. We can joyfully look forward to the time when there will have been eliminated from our cities private sources of water which is used for purposes comparable to the public supply. Even the most aggressive of us would not expect to furnish from the public sources water used for cooling in a steel mill. But there is altogether too much tendency to permit industries and individuals to use untested waters, to furnish them to their employes to drink, and to cross connect them for convenience to the public supply. They need to be checked carefully for quality and abandoned if unsatisfactory. The new order is too important not to be reproduced here. It follows:

"TREASURY DEPARTMENT
BUREAU OF THE PUBLIC HEALTH SERVICE
WASHINGTON

January 11, 1930.

"TO ALL STATE HEALTH OFFICERS:

"Hereafter water supplies used by interstate carriers for drinking and culinary purposes will not be given a full certification if cross connections exist between that supply and any other supply; except when such cross connection is with another potable public supply or a potable supply regularly examined by those in charge of the supply to which cross connected; and except, further, when such cross connections are equipped with modern protective devices approved by the State Department of Health and installed and operated under the direct control of that Department. Auxiliary intakes and by-passes are considered as cross connections.

"In making recommendations relative to certification of water supplies used by interstate carriers you should be guided by the above outlined policy.

"Respectfully,
H. S. CUMMING,
Surgeon General

It will be noted at once that the burden of study of private supplies is placed on the water utility. This is a burden, but belongs there.

One takes for granted that the terms of the bacteriological standard applied for interstate carrier water are to be used in evaluating the private supplies. The frequency of test is a matter of judgment, but the writer is inclined to feel that Mr. Tarbett's reference to annual examination of deep well supplies should not apply to cross connected industrial well supplies. So long as the physical surroundings remain unchanged and no adverse bacteriological data are accumulated, a four times yearly schedule will perhaps suffice. If adverse data are obtained, samples must be checked monthly or oftener. But here is the gist of the matter. Suppose a private supply, available for drinking, is found so bad that it falls within the group of "non connectable" supplies. Shall the State Health authorities order a disconnection and permit the water still to be used within the plant? They are in serious error if such tendency exists. Any supply which may be used by an industry's employes for drinking and yet is of such nature that it cannot be cross connected to the public supply should be interdicted for plant use. It is certain that the employes may obtain compensation for illness incurred from such a water. Can health authorities justify its use? I think not.

It appears advisable for the U. S. Public Health Service to list broad standards of "modern protective devices" for cross connections and each State Health Department should circulate such lists promptly within their territory, to the end that no lost motion ensue. Just as important would be a list of disapproved types.

The order is worth while. It is going to promote careful study of water supply distribution conditions to the end that no unsafe supplies are connected. It should be a useful aid in eliminating the unsafe supplies. It is certain that the operator of a supply previously certified will not calmly accept a "conditional" certification, especially since it appears that the final burden of condemning the unsafe private supply is a duty of the health authorities and that they—not he—will in the ultimate analysis be responsible for conditions which he as a good business man does not wish to have continue.

ELECTRO-OSMOSE TREATMENT OF BOILER WATERS[1]

By Edward Bartow[2]

An ideal boiler water is seldom found in nature. When a natural water is used in a boiler, there usually results some formation of scale, corrosion of metal, or foaming of the concentrated water. To prevent trouble, chemicals may be added to the feed water or the water may be treated externally. The addition of chemicals, or boiler compounds, is often helpful, but whenever possible it is preferable to treat the water before adding it to the boilers, and it is this method of treatment which will be discussed.

For the prevention of scale formation, addition of lime, or lime and soda, or sometimes soda alone may reduce the hardness to 50 to 85 parts per million (3 to 5 grains per gallon). Lime precipitates carbonates of calcium and magnesium which are removed by settling and filtration. Soda changes sulfates of lime and magnesium to carbonates. The lime reduces the concentration, but soda simply changes the metal in the salts to sodium without decreasing the concentration. The limit of treatment by lime and soda is the solubilities of calcium carbonate and calcium hydroxide.

A second method of treatment is base exchange with artificial or synthetic minerals. Calcium and magnesium are replaced by sodium. By this process hardness can be reduced to zero. The process, however, does not decrease the concentration of salts but changes the incrustants to non incrustants, eliminating scale formation.

Distilled water contains no solid constituents; hence it can be used in boilers without causing scale formation.

The electro-osmose process of which I shall speak later gives a water containing no mineral matter and hence can be used in boilers without causing scale formation.

Corrosion caused by acid water or by very soft waters and by dissolved oxygen can be prevented by the lime soda process, the base-exchange process and by pre-heating to remove dissolved oxygen.

[1] Presented before the Florida Section meeting, April 10, 1930.

[2] Head, Department of Chemistry, State University of Iowa, Iowa City, Iowa.

Foaming is usually caused by suspended matter and the concentration of soluble salts. It can be prevented by use of methods which remove soluble and insoluble constituents and by a careful blow-down of the boilers to prevent concentration. The lime process, distillation and electro-osmose may be considered as means for preventing corrosion.

With high pressure boilers now in use it has been found necessary to completely remove the soluble salts of sodium and potassium. Until recently distillation has been the only means available for this purpose and it has been used alone or in connection with the lime-soda and permutit treatment to prevent scaling in the distillation apparatus.

THE ELECTRO-OSMOSE METHOD OF WATER TREATMENT

The electro-osmose is a new method for the purification of water which the writer saw for the first time in the summer of 1928 in the laboratory of Phillips and Pain in Paris, France. The process was just being developed in France. It had been discovered in Germany and was there controlled by the Elektro-Osmose, A. G. At the present time, May, 1930, it is reported that many installations are in operation in Germany and France. The International Filter Company has obtained the rights for the United States and is installing machines.

To prepare pure water by distillation, it must be vaporized and condensed. To change water from the liquid to the vapor state requires a considerable amount of heat and to condense the vapor requires a considerable amount of cold. Usually coal or some fuel is used to supply heat. If coal is replaced by electricity, it is only at a greatly increased cost and the method is not considered practicable. The use of electricity in the electro-osmose process accomplishes the removal of salts by the electric current, with very little increase in temperature and therefore with much less cost. The amount of water used in condensing the vapor in the distillation process is much more than the water wasted in the electro-osmose process and hence we have here a further saving.

The purification of water is accomplished by the removal of salts from a central section of a cell through diaphragms to cells containing anode and cathode poles. By passing the water through the central compartment of a series of cells, the water in the central compartments becomes gradually purer and purer until the anions and

cations are practically all removed. The water so purified, it is claimed by French[3] and German[4] writers is equivalent to distilled water and can be obtained at a much lower cost.

In order to check these claims, and to test the applicability of the apparatus to local water, an apparatus manufactured by Elektro-Osmose, A. G. was obtained from the International Filter Company.

The experimental work was done by R. H. Jebens. The apparatus which has been described elsewhere[5] is made up of ten cells placed side by side. The purified water is passed by siphons through the central compartment of each cell. The anode and cathode waters are removed by wash water, which is fed from dripping nozzles and escapes from overflow pipes in the anode and cathode cells respectively. Cells 9 and 10 are washed with purified water.

The efficiency of the apparatus depends on the amount of current used, the amount and quality of purified water, and the amount of flow of the wash water. The quality of the water was judged by determining the electrical resistance, alkalinity, chloride, residue and ash. The resistance was determined by usual methods. The apparatus used gave a value of 176,000 ohms for the distilled water used in the laboratory. The temperature of the water tested was within $\frac{1}{2}$° of 25°C. for all readings obtained. Other tests were made in accordance with methods given in Standard Methods of Water Analysis.

The apparatus is supplied with 110 volt generator current with a maximum capacity of 30 amperes. The current is passed through the cells with connections so arranged that the potential increases as the water becomes purer. When cells 1, 2, 3, 4 are in series, 5, 6, 7 in series, 8, 9 in series, and the last cell is across the buss bar, we have what is called the 4, 3, 2, 1 system of connection. The average voltage across the first four cells is 27.5; across the next three, 37; the next two, 55; and across the last cell 110 volts. As the resistance of each cell increases from cell to cell, the voltage across the first cell is considerably lower than that of the fourth cell.

The process was started by filling the cells uniformly with water in each chamber. Wash water was regulated to run at 24 liters per hour; that is, 12 liters are used to wash the anodes and 12 to wash the cathodes. The current is turned on and when it begins to drop, feed

[3] Paul Patin, Chimie et Industrie, 19, 205 (1928).
[4] K. Illig, Z. Angew, Chem., 23, 126 (1917).
[5] A. S. Behrman, Ind. Eng. Chem., 19, 1229 (1927).

water is added at 24 liters per hour. The above rates of make-up water and wash water were called standard conditions and variations in flow are compared with this standard.

Test 1. Variation of wash water. The wash water was varied from 12 to 200 liters per hour. From 12 to 49 liters per hour no difference was noted. With 200 liters, the resistance was lowered. A variation in rate from 12 to 49 liters per hour causes no change.

Test 2. The effect of changing the rates of feed water. Zeolite softened water was used and the rates were 15, 20, and 50 liters per hour. With 50 liters per hour, there was an increase in amperage required, an increase in the alkalinity and residue, and a decrease in resistance. This shows the necessity for limiting the rate of flow of feed water.

Test 3. Varying the method of connecting cells to the buss bars. The best water was given by system 3, 2, 2, 1, 1, 1, but it required more amperes. The poorest was system 5, 3, 2. This required fewer amperes, but the water contained chloride, was alkaline, had low resistance, and high residue and ash. We would conclude that the number of cells connected, the better, and that the combination of many cells together, as for instance, 5, 3, 2, would be the least satisfactory.

Test 4. Cathode wash water as feed water. The rate of flow of wash water was made 50 liters per hour in order that sufficient cathode water might be made for use as feed water. The cathode water was collected in a drum and the precipitate allowed to settle while 50 gallons more were collected in another drum. A precipitate was formed in the center chambers of the first cells which drifted through to the rest of the cells. The precipitate consisted of calcium, magnesium, iron and aluminium, combined as hydroxides or carbonates. The quality of water deteriorated with time of operation. After 16 hours, the amperage had increased to 14, residue to 17, ash to 12.8, and methyl orange alkalinity to 4.6 with resistance decreased to 8070 ohms. At the end of 23 and 31 hours, when tests were made, the quality of the water was much worse. As would be expected the quality of the cathode water measured in terms of alkalinity was much worse than the original; the alkalinity increased from 652 to 1720 p.p.m. Under the conditions of the experiment, the use of cathode water is not to be recommended.

Test 5. Carbon dioxide added to the cathode water with the hope of improving it. Results were not entirely satisfactory. At first the

resistance increased, but at the end of 60 hours, it dropped to 2300 ohms and the alkalinity had increased to 1650 p.p.m. There would be no special advantage for continuous operation but a purer water was obtained during part of the test.

Test 6. Cathode water used as feed water and zeolite softened water for washing. No better results were obtained. The number of amperes required increased almost immediately, chloride was present in the purified water after two hours, and methyl orange alkalinity was 197. The methyl orange alkalinity of the cathode water increased from 1510 to 2500 p.p.m. There would seem to be no advantage in using this combination.

Test 7. Effect on dissolved oxygen and other substances in solution. The dissolved oxygen in the purified water is practically the same as that of the feed water. The University supply from wells as used contained 1.56 p.p.m. of dissolved oxygen. The purified water contained 1.62 p.p.m. The cathode water contained 1.37 and anode water 2.63. Since oxygen is bubbling through the anode water and hydrogen through the cathode water, we would expect these changes. Fifteen to 20 p.p.m. of chlorine are dissolved in the anode water when the rate of flow of the feed and wash waters are each 24 liters per hour and the 4, 3, 2, 1 system of connection is used. The pH of the purified water is between 4.5 and 5 as determined by the LaMotte Standard pH indicators. The ash from the purified water is composed of from 90 to 95 percent of silica (SiO_2).

OBSERVATIONS ON OPERATION

When the machine is started with cells containing raw water, the current consumed is exceptionally high in some of the cells. With relatively high concentration of dissolved salts in the water, foam forms on these cells. As soon as the partially purified water reaches the foaming cells, the current used decreases and foaming ceases in an hour after the machine is started.

When zeolite water was used, a fine deposit formed on the diaphragms. Cleaning the diaphragms once a month would obviate this difficulty. If the water supply to the apparatus contains any suspended matter or sediment, the nozzles may clog. The apparatus should be seen at least twice daily to clean the nozzles. The supply tanks for washing the last two cells must be kept full of pure water. With the water used, it was found necessary to clean the cells themselves once in two weeks.

INTERPRETATION OF RESULTS

In our experiments zeolite softened water and regular tap water produced water of the same quality. The current used varied from 8.7 to 9.7 amperes. Chlorides were zero, alkalinity to methyl orange was zero to 1 p.p.m.; resistance 22,100 to 26,900 ohms; residues 12.8 to 14.3 p.p.m.; ash 10.6 to 11.7 p.p.m. The ash from the purified water contained 90 to 95 percent of silica. The raw water has an average of 9.5 mg. per liter of silica. Since 90 percent of ash will amount to 9.5 to 10.5 mg. of silica per liter for the purified water, it is evident that little, if any, of the silica is removed from the water by the process. The material determined as silica is therefore not in solution in the water in ionic form but in molecular form, possibly of colloidal size. The residue is brown in color and turns black on heating. The ash is white or cream colored. Concentrated hydrochloric acid dropped on the ash does not cause effervescence. The loss of weight of this residue on heating is assumed to be due chiefly to oxidation of organic material which is not removed by the electro-osmose process.

The electro-osmose process removes all but 2 or 3 mg. per liter of electrolytes. With a reduced flow of feed water, the residue and ash decreased. The resistance of the purified water did not increase. It would therefore seem that non-electrolytes were removed by the slower rate. The 3, 2, 2, 1, 1, system of connection gave the purest product as measured by decrease in the amount of ash and increase in the amount of resistance.

Partially purified water obtained as with purified water to 50 liters per hour rate with a total residue of 65 mg. per liter, can be obtained at an operating cost of 43 cents per 100 gallons of water. This is on the basis of 4 cents per KWH, in a plant to give 1000 gallons of water per hour. Using barium carbonate and calcium hydroxide, the operating cost at the same rate would be 54 cents per 100 gallons of water (barium carbonate $60 per ton, lime $8.50 per ton).

The cathode water contains hydroxide, the tap water contains bicarbonate. A combination of hydroxide and carbonate in the first cell in the presence of calcium causes a precipitate of calcium carbonate. Magnesium, iron, and aluminium will form precipitates in the presence of excess of hydroxide. The cathode water and tap water must therefore not be mixed in the machine. With carbonated tap water, there was less precipitation. The precipitates thus formed

drift through the cells. If the solution is not saturated, they will tend to dissolve increasing the work of the last cells and some of the precipitate will eventually reach the purified water tank. If calcium, magnesium, iron and aluminium are removed by lime soda or lime barium treatment, the precipitation will be prevented. Cathode water which is essentially lime water can be used in conjunction with soda.

SUMMARY

A water with a residue of less than 15 p.p.m. can be obtained from the water supply at the University of Iowa which has a total residue of 725 p.p.m. The residue is chemically inert; therefore, the water will serve for most of the common uses of distilled water. Cathode water cannot be mixed with tap water for feed water without first treating the tap water with either the lime soda or lime barium treatment.

The advantages claimed by the Elektro-Osmose, A. G. were all substantiated but one. Time and energy are lost in starting the machine for the water produced is not of desired quality until an hour after the machine is started. The cathode water could be used industrially in any process where lime water is used. The anode water could be used as bleaching and disinfecting wash water. Less than one-half the electrical energy would be required to reduce the residue from 600 to 300 p.p.m., than from 300 p.p.m. to zero.

TYPHOID FEVER IN THE LARGE CITIES OF THE UNITED STATES IN 1929[1]

This report concerns the same eighty-one cities of more than a hundred thousand population that were discussed in the reports for 1927 and 1928.[2]

Two of the twelve New England cities had no deaths from typhoid during 1929 (table 1), a record made once before by both cities (Hartford in 1924, New Bedford in 1922). Both Fall River and Springfield report that the only typhoid deaths occurring within the city limits were those of non-residents. Bridgeport has maintained a remarkably even rate for four years (one death annually in 1929, 1928, 1927 and 1926). The four cities that had a clean slate in 1928 (Lowell, Lynn, New Haven and Springfield) all had some typhoid mortality in 1929, Lowell a notable amount. The typhoid death rate in the latter city in 1929 was, in fact, higher than the 1921–1925 average. Since the deaths in Lowell number more than those in Fall River, Hartford, New Bedford, New Haven and Springfield combined, with a

[1] Reprinted from the Journal of the American Medical Association, 94: 20, May 17, 1930, p. 1574. Preceding articles were published in the same Journal, May 31, 1913, p. 1702; May 9, 1914, p. 1473; April 17, 1915, p. 1322; April 22, 1916, p. 1305; March 17, 1917, p. 845; March 16, 1918, p. 777; April 5, 1919, p. 997; March 6, 1920, p. 672; March 26, 1921, p. 860; March 25, 1922, p. 890; March 10, 1923, p. 691; Feb. 2, 1924, p. 389; March 14, 1925, p. 813; March 27, 1926, p. 948; April 9, 1927, p. 1148; May 19, 1928, p. 1624; May 18, 1929, p. 1674.

[2] The deaths from typhoid in each city are those reported to us by the respective health departments. It should be noted that the figures include all typhoid deaths that have occurred within the city limits, non-residents as well as residents. In some instances this undoubtedly gives an exaggerated impression of the amount of typhoid in a community, but at present statisticians are agreed that "the attempt to eliminate the deaths of non-residents would often result in an understatement of the true mortality" (Bureau of the Census, Mortality Statistics, 1912, p. 13). Except where the city health departments sent us an estimate of the 1929 population, as noted in the tables, the rates have been calculated on the basis of the midyear population figures for 1928 plus the 1927–1928 increment, as the U. S. Bureau of Census has not made estimates for city populations as of July 1, 1929. It is recognized that at this time, just before the decennial census, any population estimates are relatively unreliable; hence the specific rates as figured are not definite.

total population nearly seven times as great, it seems probable that some special factor increasing the amount of typhoid was operative in Lowell in 1929. The rate in Boston was also somewhat higher in 1929 than in the two preceding years, the increased rate in this city being chiefly responsible for bringing the average of the New England group up to 1.32 as compared with 0.90 in 1928 and 1.26 in 1927 (table 12).

The cities of the Middle Atlantic group (table 2) make a particularly good showing. For the first time since these summaries were undertaken, the typhoid death rate for the group is lower than

TABLE 1

Death rates of cities in New England States from typhoid per hundred thousand population

	1929	1928	1927	1926	1921–1925	1916–1920	1911–1915	1906–1910
Hartford	0.0	1.2	1.8	1.2	2.5	6.0	15.0	19.0
New Bedford	0.0	0.8	3.3	0.7	1.7	6.0	15.0	16.1
Bridgeport	0.6	0.6	0.6	0.6	2.2	4.8	5.0	10.3
Fall River	0.7	4.5	2.3	0.8	2.3	8.5	13.4	13.5
Springfield	0.7	0.0	0.0	0.7	2.0	4.4	17.6	19.9
New Haven	1.0	0.0	0.0	2.2	4.4	6.8	18.2	30.8
Worcester	1.0	0.5	3.1	0.5	2.3	3.5	5.0	11.8
Boston	1.6	0.6	1.1	1.8	2.2	2.5	9.0	16.0
Cambridge	1.6*	1.6	0.8	4.9	4.3	2.5	4.0	9.8
Providence	1.7	1.7	0.4	0.7	1.8	3.8	8.7	21.5
Lynn	1.9	0.0	0.9	3.8	1.6	3.9	7.2	14.1
Lowell	4.4	0.0	2.6	0.9	2.4	5.2	10.2	13.9

* Based on population estimate furnished by the health department: 127,125.

that of the New England group (table 12). Reading, which had a very high typhoid rate from 1906 to 1915, did not record a single fatality from this cause in 1929, breaking its own record and leading the list of cities in this group. Such an improvement must be regarded as a great achievement in preventive medicine. Jersey City, Syracuse, Newark, Rochester and Erie have very low rates, in several instances also making a new record. Yonkers, after the remarkable record of three years with no typhoid fatality, reports two deaths from this cause in 1929. Camden, for the second year in succession, brings up the foot of the list with a 1929 rate of 5.8; there seems to be no reason why Camden should usually have a higher rate than Philadelphia. Philadelphia reports for 1929 the rate of 0.7, an amazing achievement for a city not long ago one of the great typhoid centers

of the country. For the second year in succession Philadelphia has done better than New York, although the latter community itself makes a new low record in 1929 (1.2). The excellent brief summaries of typhoid cases and deaths in New York in the Weekly Bulletin of the Department of Health (e.g., September 21 and

TABLE 2

Death rates of cities in Middle Atlantic States from typhoid per hundred thousand population

	1929	1928	1927	1926	1921–1925	1916–1920	1911–1915	1906–1910
Reading	0.0	2.6	1.7	2.6	6.0	10.0	31.9	42.0
Jersey City	0.3*	0.6	1.2	1.9	2.7	4.5	7.2	12.6
Syracuse	0.5	0.5	1.5	1.1	2.3	7.7	12.3	15.6
Newark	0.6	1.0	1.3	1.5	2.3	3.3	6.8	14.6
Rochester	0.6	0.9	1.2	4.0	2.1	2.9	9.6	12.8
Erie	0.7	0.8†	1.5	0.8	2.3	6.9	49.0	46.6
Philadelphia	0.7‡	0.8	1.4	1.9	2.2	4.9	11.2	41.7
Utica	0.9	1.9	2.9	0.0	3.9¶			
New York	1.2	1.4	1.3	1.9	2.6	3.2	8.0	13.5
Scranton	1.4§	1.4	0.7	4.2	2.4	3.8	9.3	31.5
Yonkers	1.6	0.0	0.0	0.0	1.7	4.8	5.0	10.3
Elizabeth	1.7	0.0	0.9	1.0	2.4	3.3	8.0	16.6
Buffalo	1.9	2.3	2.4	5.0	3.9	8.1	15.4	22.8
Paterson	2.0	1.4	0.0	1.4	3.3	4.1	9.1	19.3
Trenton	2.1	2.1	1.5	2.2	8.2	8.6	22.3	28.1
Pittsburgh	2.3	3.4	1.9	2.7	3.9	7.7	15.9	65.0
Albany	3.3	0.8	3.3	0.0	5.6	8.0	18.6	17.4
Camden	5.8	4.4	0.7	4.6	5.9	4.9	4.5	4.0

* Based on population estimate furnished by health department: 329,256.

† The rate of 5.3 recorded for Erie in our table for 1928 was not correct, because of an error in the information sent us.

‡ Population estimate furnished by health department: 2,092,576.

¶ Data for 1925 only.

§ The number of Scranton typhoid deaths was furnished by the state registrar, Harrisburg, Pa.

November 30, 1929) show that, even with the careful investigation of each case that is always made by the New York City Department of Health, the mode of infection was not ascertainable in one-third or more of the cases. During the summer months, bathing in polluted waters seems to be still an important factor, although the number of cases from this cause was less in 1929 than in 1928. A high proportion of the total cases (more than one-third in 1928 and 1929)

seems to have been contracted outside the city. Fifty or more cases of typhoid occurred in 1929 among New York City girls who had been spending their vacation in a summer camp in Pennsylvania.

TABLE 3

Death rates of cities in South Atlantic States from typhoid per hundred thousand population

	1929	1928	1927	1926	1921–1925	1916–1920	1911–1915	1906–1910
Norfolk	0.5*	1.6	1.1	1.7	2.8	8.8	21.7	42.1
Jacksonville	0.7	2.1	7.2	8.8				
Wilmington	0.8	4.7	3.2	2.4	4.7	25.8†	23.2‡	33.0
Richmond	1.5	3.1	0.0	2.6	5.7	9.7	15.7	34.0
Washington	2.3	2.7	1.8	2.5	5.4	9.5	17.2	36.7
Baltimore	2.6	3.8	1.8	4.7	4.0	11.8	23.7	35.1
Atlanta	6.5	7.4	14.0	17.2	14.5	14.2	31.4	58.4

* Population estimate furnished by the health department: 184,200.
† 1916 only.
‡ Lacks 1913.

TABLE 4

Death rates of cities in East North Central States from typhoid per hundred thousand population

	1929	1928	1927	1926	1921–1925	1916–1920	1911–1915	1906–1910
Toledo	0.3	4.8	2.9	4.7	5.8	10.6	31.4	37.5
Milwaukee	0.4	0.7	0.9	1.7	1.6	6.5	13.6	27.0
Cleveland	0.5	0.6	1.0	1.4	2.0	4.0	10.0	15.7
Chicago	0.6	0.5	0.7	0.8	1.4	2.4	8.2	15.8
Grand Rapids	0.6	0.6	1.9	1.3	1.9	9.1	25.5	29.7
Canton	0.8	0.8	0.0	3.6	3.3	8.9		
Detroit	0.9	1.0	1.2	2.2	4.1	8.1	15.4	22.8
Youngstown	1.0*	0.0	2.4	0.0	7.2	19.2	29.5	35.1
Flint	1.3	3.4	2.1	0.7	4.6	22.7	18.8	46.9
Indianapolis	1.5	3.6	1.3	5.4	4.6	10.3	20.5	30.4
Dayton	1.6	2.7	1.7	2.3	3.3	9.3	14.8	22.5
Akron	1.7	0.4	2.8	1.5	2.4	10.6	21.0	27.7†
Cincinnati	1.9	1.7	3.9	2.7	3.2	3.4	7.8	30.1
Columbus	2.3	1.7	2.0	1.7	3.5	7.1	15.8	40.0

* Population estimate furnished by health department: 189,000.
† Data for 1909 and 1910 only.

The cities in the South Atlantic group (table 3) without exception have lower rates in 1929 than in 1928. This brings the rate for the

whole group (table 12) to a figure less than half that of 1926. Norfolk, which has had quite consistently the lowest rate in the group for a series of years, again tops the list. Jacksonville reports the remarkably good figure of 0.7 and Wilmington of 0.8. It is especially encouraging to notice that the relatively high typhoid in Atlanta is gradually yielding to the steady hammering away at milk supply

TABLE 5

Death rates of cities in East South Central States from typhoid per hundred thousand population

	1929	1928	1927	1926	1921–1925	1916–1920	1911–1915	1906–1910
Louisville	2.6	2.7	3.1	6.7	4.9	9.7	19.7	52.7
Memphis	6.2*	11.6	14.5	19.2	18.9	27.7	42.5	35.3
Birmingham	7.0	7.2	12.9	8.5	10.8	31.5	41.3	41.7
Nashville	12.8	15.0	16.0	35.0	17.8	20.7	40.2	61.2

* Population estimate furnished by health department: 192,515.

TABLE 6

Death rates of cities in West North Central States from typhoid per hundred thousand population

	1929	1928	1927	1926	1921–1925	1916–1920	1911–1915	1906–1910
Duluth	0.0	0.0	2.7	0.8	1.7	4.4	19.8	45.5
Omaha	0.4	2.7	0.9	1.8	3.3	5.7	14.9	40.7
Minneapolis	0.6	0.2	0.7	1.4	1.9	5.0	10.6	32.1
St. Paul	1.0	1.3	2.8	1.2	3.4	3.1	9.2	12.8
St. Louis	1.5*	2.2	1.9	2.3	3.9	6.5	12.1	14.7
Kansas City, Kan	2.5	1.7	0.0	4.3	5.0	9.4	31.1	74.5†
Des Moines	3.2	1.3	3.3	2.7	2.2	6.4	15.9	23.7
Kansas City, Mo	3.2	2.3	2.9	3.5	5.7	10.6	16.2	35.6

* Population estimate furnished by the health department: 856,000.

† Lacks data for 1906, 1907.

and other typhoid factors. Those sanitarians who may still feel that a warm climate offers an insurmountable barrier to any sweeping reduction in typhoid need only inspect the figures of the cities in this group for the last four years to be convinced that remarkable results can be obtained by persistence in intelligently directed methods for typhoid control. Typhoid seemed firmly entrenched in these cities in 1906–1910, but in the space of twenty years it has been almost completely overthrown. The history of this group of cities abun-

dantly justifies the conclusion that typhoid is a preventable disease and should not be allowed to scourge, year after year, any city, whatever its climate and geographic position.

The East North Central cities for the second time in five years have the distinction of the lowest rate of any group in the country, 0.86 (table 12), considerably less than that for the New England and Middle Atlantic cities and better than its own previous best record. Probably in few city groups anywhere with a population as large and heterogeneous as represented here has so low a typhoid rate ever been reported. The three largest cities in this group (Chicago, Detroit and Cleveland) all report rates under 1.0 (table 4). Milwaukee continues to furnish a brilliant example of what water chlorination can do in the elimination of typhoid. Toledo spurts from the foot of the list in 1928 to the head in 1929.

TABLE 7

Death rates of cities in West South Central States from typhoid per hundred thousand population

	1929	1928	1927	1926	1921–1925	1916–1920	1911–1915	1906–1910
Tulsa	2.1	3.5	8.7	14.3	16.2*			
Fort Worth	2.8	7.0	4.3	10.7	6.1	16.3†	11.9	27.8
Houston	2.8	6.0	5.6	6.0	7.6	14.2	38.1	49.5‡
San Antonio	3.1	2.3	5.7	7.8	9.3	23.3	29.5	35.9
El Paso	4.9	10.2	7.9	9.2	10.8	30.7	42.8	
Oklahoma City	6.2§	10.0	6.4					
New Orleans	9.1	7.2	8.0	18.6	11.6	17.5	20.9	35.6
Dallas	9.4	5.0	6.6	8.9	11.2	17.2		

* Lacks data for 1921 and 1922.

† Lacks data for 1918 and 1919.

‡ Data for 1910 only.

§ Population estimate furnished by health department: 160,000.

The East South Central cities (table 5) again show an improvement over the preceding year, all of them having a lower typhoid mortality than in 1928. The improvement in Memphis is especially noteworthy. Nashville again has the highest rate of this group and the highest in the United States. An organized campaign against typhoid in this city would probably reduce the disease to a point at which the rates would compare favorably with those in Birmingham, where the rates have far outstripped Nashville in improvement in the last few years. There is certainly no reason why Nashville should

continue to have a rate higher than Louisville, Birmingham or Memphis.

The cities of the West North Central group again make, as usual, a good showing (table 6). Duluth matches its 1928 record of no typhoid deaths, and Omaha, which twenty years ago had an average rate of 40.7, has in 1929 a rate only one-hundredth as great (0.4). St. Louis, like others of the large cities of the country, breaks its own record in 1929 with a rate (1.5) not far above that of New York (1.2). Des Moines and Kansas City, Mo., could probably reduce their typhoid rates somewhat by a little detective work.

TABLE 8

Death rates of cities in Mountain and Pacific States from typhoid per hundred thousand population

	1929	1928	1927	1926	1921–1925	1916–1920	1911–1915	1906–1910
Spokane	0.0	1.8	0.9	6.5	4.4	4.9	17.1	50.3
Salt Lake City	0.7	2.9	2.2	0.7	6.0	9.3	13.2	41.1
San Francisco	1.0	3.4	1.7	2.5	2.8	4.6	13.6	27.3
Los Angeles	1.1	1.5	1.0	1.1	3.0	3.6	10.7	19.0
Oakland	1.1*	1.1	2.2	0.8	2.0	3.8	8.7	21.5
San Diego	1.6	1.7	0.9	0.9	1.6	7.9	17.0	10.8
Tacoma	1.7	0.0	2.8	3.8	3.7	2.9	10.4	19.0
Denver	2.0	2.7	2.8	3.5	5.1	5.8	12.0	37.5
Portland	2.3†	2.1	2.1	2.5	3.5	4.5	10.8	23.2
Seattle	2.3	1.3	2.7	2.3	2.6	2.9	5.7	25.2

* Population estimate furnished by the health department: 280,900.

† Population estimate furnished by the health department: 348,845.

The West South Central group (table 7) still has nearly the highest rate in any geographic division of the United States (table 12). There are signs, however, that the progressive communities in Texas and elsewhere are not going to be satisfied with their status. Tulsa has taken a long step in typhoid reduction, and Fort Worth, Houston and San Antonio are not far behind. Dallas will find itself suffering from an inferiority complex unless some definite and permanent improvement takes place before long. New Orleans has a hard problem but should be encouraged by what it has already accomplished, and especially by what has been done in such cities as Memphis, Atlanta and Louisville.

The group of Mountain and Pacific cities (table 8), which has usually made a pretty good record, shows a material reduction in 1929

as compared with 1928 (table 12). Spokane for the second time in its history (the other was in 1919) reports a perfectly clear record, the only other city in this group making such a record being Tacoma

TABLE 9

Death rates from typhoid in 1929

Honor Roll (from 0.0 to 1.9 deaths per hundred thousand)			
DULUTH	0.0	Utica*	0.9
HARTFORD	0.0	New Haven	1.0
NEW BEDFORD	0.0	St. Paul	1.0
READING	0.0	San Francisco	1.0
SPOKANE	0.0	Worcester	1.0
Jersey City	0.3	Youngstown	1.0
Toledo	0.3	Los Angeles	1.1
Milwaukee	0.4	Oakland	1.1
Omaha	0.4	New York	1.2
Cleveland	0.5	Flint	1.3
Norfolk	0.5	Scranton	1.4
Syracuse	0.5	Indianapolis	1.5
Bridgeport	0.6	Richmond	1.5
Chicago	0.6	St. Louis	1.5
Grand Rapids*	0.6	Boston	1.6
Minneapolis	0.6	Cambridge, Mass	1.6
Newark	0.6	Dayton	1.6
Rochester, N. Y	0.6	San Diego	1.6
Erie	0.7	Yonkers	1.6
Fall River*	0.7	Akron	1.7
Jacksonville	0.7	Elizabeth	1.7
Philadelphia	0.7	Providence	1.7
Salt Lake City*	0.7	Tacoma	1.7
Springfield, Mass.*	0.7	Buffalo	1.9
Canton	0.8	Cincinnati	1.9
Wilmington	0.8	Lynn	1.9
Detroit	0.9		
First Rank (from 2.0 to 4.9)			
Denver	2.0	Baltimore	2.6
Paterson	2.0	Louisville	2.6
Trenton	2.1	Fort Worth	2.8
Tulsa	2.1	Houston	2.8
Columbus	2.3	San Antonio	3.1
Pittsburgh†	2.3	Des Moines	3.2
Portland, Ore	2.3	Kansas City, Mo	3.2
Seattle	2.3	Albany	3.3
Washington	2.3	Lowell	4.4
Kansas City, Kan	2.5	El Paso	4.9

TABLE 9—*Concluded*

Second Rank (from 5.0 to 9.9)			
Camden†	5.8	Birmingham†	7.0
Memphis	6.2	New Orleans	9.1
Oklahoma City	6.2	Dallas	9.4
Atlanta	6.5		
Third Rank (above 10.0)			
Nashville	12.8		

* We are informed that in Fall River, Grand Rapids, Salt Lake City, Springfield, Mass., and Utica, N. Y., the only typhoid deaths reported were in non-residents.

† Cities in which a considerable proportion of the total typhoid deaths for 1929 occurred in non-residents are as follows (see also preceding footnote): Pittsburgh, 12 non-resident, total for city, 16; Camden, 5 non-resident, total for city, 8; Birmingham, 9 non-resident, total for city, 16.

in 1928. San Francisco had apparently less typhoid in 1929 (1.0) than ever before. Denver also reached its low figure of 2.0. The rates in this group are remarkably uniform.

Five of the eighty-one cities considered in this study have had no typhoid deaths in 1929 (table 9). This is a smaller number with

TABLE 10

Number of cities with various typhoid death rates

	NUMBER OF CITIES	10.0 AND OVER	5.0 TO 9.9	2.0 TO 4.9	1.0 TO 1.9	0.1 TO 0.9	0.0
1906–1910	74	72	2	0	0	0	0
1911–1915	75	55	18	2	0	0	0
1916–1920	77	19	29	29	0	0	0
1921–1925	79	8	15	46	10	0	0
1926	80	6	10	27	19	14	4
1927	81	4	8	26	23	13	7
1928	81	4	6*	25	20	17*	9
1929	81	1	7	20	25	23	5

* Revised from figures given in our 1928 report on account of correction for Erie.

perfectly clear records than was reported in 1927 and 1928. Twenty-eight cities, however, had a typhoid death rate of less than 1.0 in 1929 as against twenty-six in 1928 (table 10). Only one city (Nashville) had a rate of over 10.0 in 1929, as against four in each of the two preceding years. This contrasts with the average rates for 1911–1915,

when fifty-five (out of seventy-five cities reporting) had rates of 10.0 or higher.

Perhaps the most remarkable feature of this year's report is the evidence it gives of the continued decline in typhoid in the United States. Not only was the typhoid death rate in a city population of

TABLE 11

*Total typhoid rate for seventy-four cities, 1910–1928**

	POPULATION	TYPHOID DEATH	TYPHOID DEATH RATE PER 100,000
1910	22,286,000	4,586	20.58
1911	22,916,700	3,883	16.94
1912	23,535,450	3,077	13.07
1913	24,151,936	3,222	13.34
1914	24,776,777	2,744	11.07
1915	25,392,422	2,373	9.34
1916	25,928,745	2,154	8.31
1917	26,528,213	1,963	7.40
1918	26,737,190†	1,796†	6.72
1919	27,373,579†	1,141†	4.17
1920	28,182,528	1,074	3.81
1921	28,509,732	1,130	3.96
1922	28,947,007	955	3.30
1923	29,580,000	936	3.16
1924	30,155,014	937	3.11
1925	30,938,501	1,067	3.45
1926	31,667,424	895	2.83
1927	32,492,123	638	1.96
1928	33,116,784	621‡	1.89‡
1929	33,984,261	531	1.56§

* The following seven cities are omitted from this table because data for the full period are not available: Canton, Dallas, Jacksonville, Oklahoma City, Tulsa, Utica, Wilmington.

† Lacks data for Fort Worth.

‡ Revised from figure given in our 1928 report on account of correction for Erie.

§ The rate for the eighty-one cities in 1929 is 1.62.

approximately thirty-four million as low as 1.56 (table 11), but the actual number of typhoid deaths (531) in this population was less than half the corresponding number as recently as 1925 (1,067). Indeed, since these summaries were started in 1910, the typhoid death rate in the large cities of the United States has been cut in half with great regularity every five or six years. During the years 1922 to 1925

TABLE 12

Total typhoid death rate per hundred thousand population for eighty-one cities according to geographic divisions

	POPULATION	1929		1928		1927	1926	1925
		Typhoid deaths	Typhoid death rate	Typhoid deaths	Typhoid death rate	Typhoid death rate	Typhoid death rate	Typhoid death rate
New England	2,575,282	34	1.32	23	0.90	1.26	1.51	2.37
Middle Atlantic	12,034,265	149	1.24	171*	1.45*	1.41	2.09	2.97
South Atlantic	2,321,300	58	2.50	85	3.72	3.39	5.38	5.71†
East North Central	8,715,100	75	0.86	94	1.10	1.31	1.69	2.19
East South Central	899,915	55	6.11	68	7.68	10.07	14.47	14.30
West North Central	2,636,300	41	1.55	43	1.65	1.86	2.22	3.31
West South Central	1,875,054	104	5.55	109	6.18	6.71	11.69‡	13.27‡
Mountain and Pacific	4,001,445	54	1.35	72	1.92	1.74	1.98	2.19

* Revised from figures given in our 1928 report on account of correction for Erie.

† Lacks data for Jacksonville.

‡ Lacks data for Oklahoma City.

it seemed as if the rate of progress was being permanently checked, but the last four years has again witnessed an astonishing improvement in typhoid mortality.

ABSTRACTS OF WATER WORKS LITERATURE[1]

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Uncombined Iodotannic Reagent. Iodotannic Value of Waters. G. CARPENTIER and J. FERCOCQ. Union pharmaceutique, 69: 259–61, 1928; Chimie et industrie, 20: 1071–2, 1928. From Chem. Abst., 23: 1837, April 20, 1929. Combined iodotannic solution prepared by warming 0.4 percent tannic acid solution with 0.2 percent iodine does not give any color with distilled, spring, or river water. Uncombined reagent prepared by adding 30 grams Codex tincture of iodine (containing $\frac{1}{15}$ of its weight of iodine) to 1 liter of 0.4 percent tannic acid gives no color with distilled water; with natural waters it gives carmine rose color which gradually changes to yellowish on adding excess of reagent. Number drops of reagent required to color 10 cc. water and then render it colorless or yellowish depends on composition of water, and can be used to determine it. Suggested that this be called iodotannic number. Reaction is due to presence of neutral and alkaline salts which, in dilute solution, have pH value appreciably higher than 7. Reagent therefore constitutes a very sensitive indicator in alkaline solution. Nature of iodine complex formed has not been determined.—*R. E. Thompson.*

Determination of Minute Quantities of Lead by Electrolysis. A. SEISER, A. NECKE and H. MÜLLER. Z. angew. Chem., 42: 96–8, 1829. From Chem. Abst., 23: 1838, April 20, 1929. After separating as lead sulfate, dissolve in hot 20 percent nitric acid, evaporate to dryness, add 1–1.5 cc. of nitric acid (free from nitrous acid), and 5 cc. of 1 percent copper sulfate solution, and electrolyze with current of 2 amperes at 3.3 volts. Platinum gauze electrodes are recommended. After 45 minutes remove anode, wash with water, shake off as much water as possible, and dip into solution of tetramethyldiaminodiphenylmethane in acetic acid. Compare blue color with that similarly developed with lead dioxide obtained by electrolysis of lead nitrate solutions of known concentration.—*R. E. Thompson.*

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[1] Vacancies on the abstracting staff occur from time to time. Member desirous of cooperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

Penetration of Ultra-Violet Light into Pure Water and Sea Water. E. O. HULBURT. J. Optical Soc. Am., 17: 15–22, 1928. From Chem. Abst., 23: 1815, April 20, 1929.—*R. E. Thompson.*

Yankton Abandons Artesian Wells for Missouri River. F. G. BRUECKMANN. Eng. News-Rec., 102: 990–2, 1929. The new water supply of Yankton, S. D., derived from the Missouri River, is described. For more than 40 years water had been obtained from artesian wells. This water had a total hardness of 960 p.p.m., permanent hardness of 830 p.p.m., and Fe content of 2.5 p.p.m., the latter causing widespread staining of plumbing fixtures. Intake shafts were constructed in the piers of the Meridian highway bridge, inlet openings being provided at two elevations—just below mean water level and below the stream bed. Single coarse screens were placed in the upper openings and 2 screens with coarse gravel between were provided in the lower openings. If satisfactory water is obtained through the latter, the supply will be treated only with Cl_2, but as river water from the higher inlets may have to be employed, provision has been made for construction of a plant for treatment by coagulation and filtration in addition to chlorination. Deep well turbine pumps have been installed in two shafts, necessitating crossing the lift span of bridge, which is operated once each year. Details of crossing included.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Public Water Supplies of Holland Serve 60 Percent of Population. W. F. J. M. KRUL and F. A. LIEFRINCK. Eng. News-Rec., 102: 966, June 13, 1929. Public water supplies had been provided for 70 cities and 358 rural towns in Holland on January 1, 1928, number of supplies being 135, of which 98 were publicly and 37 privately owned. These supplies serve 60.5 percent of Holland's population of 7,600,000. Average daily per capita consumption in 1927 was 98.5 liters (26 United States gallons). Most industrial plants have separate supplies. Of the 428 towns and cities using these supplies, 49 are supplied from rivers, 136 from the dunes and 243 from other ground water sources. Typhoid mortality in Amsterdam, 1854–1927, is shown graphically.—*R. E. Thompson.*

What Do You Pay for When You Buy a Load of Sand? E. R. DAWLEY. Kansas State Agricultural College, Manhattan. Eng. News-Rec., 102: 1032, 1929. Data are given on the bulking of sand. As average air voids in dry sand are about 33 percent and bulking may be as much as 20–30 percent, the actual solid content of sand averages only about 50 percent. The extent of bulking depends principally on the nature of the sand and its gradation, the manipulation, and amount of moisture present. Maximum bulking occurs with moisture content of about 3 to 3.5 percent in the case of coarse sand and with about 5 percent in the case of fine sand. Volume then decreases with increasing water content until at 20–30 percent the sand occupies its original dry volume. Simple tests for determining bulking are included.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Construction Camp and Program for San Gabriel Dam. E. C. EATON. Eng. News-Rec., 102: 1030–2, June 27, 1929. Data given on preliminary work under

way on San Gabriel dam of Los Angeles County Flood Control District, which will require unprecedented mass of approximately 4,000,000 cubic yards of concrete. Structure is to be completed in 6 years. Actual construction work thus far has been confined to rough excavation on west abutment.—*R. E. Thompson.*

The Tri-State Delaware River Compact. BENJAMIN FRANKLIN. Eng. News-Rec., **102**: 1044, June 27, 1929. Discussion of compact from viewpoint of Pennsylvania. Serious disadvantages to Pennsylvania and, in some measure, to western New Jersey may be summed up as follows: (1) Allotment of water is unequal and is not in proportion to respective watershed areas within boundaries of the signatory states. (2) Diversion of large amount of the best quality water into other watersheds. (3) Surrender of control of very important tributaries of Delaware River which are entirely within state limits by State of Pennsylvania to commission of which majority may not be friendly to welfare of the state.—*R. E. Thompson.*

Water and Sewage Control for State Institutions. GEORGE L. HALL and A. W. BLOHM. Bur. of Sanitary Eng., Maryland. Eng. News-Rec., **103**: 52, 1929. A brief description of a plan developed in Maryland for paid supervision of water and sewage works at state institutions by the Bureau of Sanitary Engineering. Results obtained to date at 4 of the 9 state institutions have been encouraging. All state institutions will be included in the plan after October 1, 1929. The yearly sums payable by the various institutions will vary from $250 to $600.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Centrifugal and Deep-Well Pumps Draw from One Well. Eng. News-Rec., **102**: 956–8, June 13, 1929. It was found that new well at Born Court pumping station, Kalamazoo, Michigan, could furnish 3 m.g.d. within limits of suction lift and 7.2 m.g.d. by drawing water down in well to 50 feet below surface. Pump arrangement devised to meet both conditions is described and illustrated. Problem of using both deep well and horizontal suction pump on same well was solved by placing drop pipe inside suction pipe, using annular space between as suction connection. Equipment consists of 7.2-m.g.d. deep well pump and two 3-m.g.d. horizontal contrifugal pumps. Either of latter can be operated alone, drawing water through annular suction space and check valve and discharging into pressure header. If high rate of supply is required, the deep well pump is started, after which the second horizontal pump is cut in. The deep well pump discharges into suction header of the horizontal pumps, which then deliver the water into the pressure header. Station is operated by remote control from main pumping station, several hundred feet distant. Check valves on discharge of horizontal pumps are connected with electrical control system which shuts down pump 45 seconds after starting if water does not begin to flow.—*R. E. Thompson.*

Elimination of Red Water Trouble at Ashbury Park, N. J. STUART K. KNOX. Eng. News-Rec., **102**: 1040, 1929. The plant of Asbury Park consisted of 5 deep wells pumped by air lift, 0.2 million gallon settling basin, and pressure

filters with a nominal capacity of 1.6 million gallons per day, the latter often being operated at twice the rated capacity. The well water is soft and contains 27.5 p.p.m. free CO_2 and 8.5 p.p.m. Fe. The corrosive nature of the effluent, together with its Fe content, resulted in red water. To correct this condition, an aerator consisting of series of steel pans with alternate perforated and plain sections was installed, timber inlet and outlet flumes were constructed in basin to eliminate short circuiting and 2 additional 0.5-million gallon per day filters were added. The sand in the old filter units, which had an effective size of 0.92–1.03 mm., was replaced with sand of 0.49 mm., and a 25,000-gallon wash water tank was erected, so that all the filters could be washed with filtered water. These improvements eliminated the overloading and provided effective filtration.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Sluicing Débris from a Clogged Water Power Conduit. Eng. News-Rec., 102: 959, June 13, 1929. Brief outline of the clearing out of the 2400-foot length of 9½ x 12½-foot tunnel with intake just below San Francisquito power house, which became clogged with débris during flood following collapse of St. Francis dam. Material, which was chiefly sand and gravel, was removed by sluicing.—*R. E. Thompson.*

Standing Section of St. Francis Dam Razed with Dynamite. Eng. News-Rec., 103: 51, July 11, 1929. Brief illustrated description of dynamiting of section of St. Francis dam which remained standing after failure of structure. —*R. E. Thompson.*

Tulsa Building a 24-m.g.d. Water Purification Plant. F. M. VEATCH. Eng. News-Rec., 102: 964–6, 1929. Since 1924, Tulsa, Okla., has been supplied with water impounded in Spavinaw Creek and delivered to 500-million gallon storage reservoir known as Mohawk Lake through a 54- and 60-in. concrete conduit 55 miles long. From Mohawk Lake the water is pumped 4 miles to the city. A purification plant, at present under construction, and other improvements and described and illustrated. The water at present enters and leaves Mohawk Lake through a single intake structure and consequently there is no general movement of the water other than that induced by wind. A new inlet will be constructed at the other end of the lake which will render the entire area of the reservoir available for settling. The settled water will be aërated by compressed air introduced through diffuser plates in the flume connecting the lake and the plant, coagulated with lime and alum, filtered through 6 rapid sand filters and finally chlorinated. Provision will be made for enlargement of plant to 80 m.g.d. Two mixing basins, 40 feet in diameter and 66.5–22 feet deep, with tangential inlets, will provide mixing period of 22 minutes. Velocity necessary for mixing will ordinarily be obtained by flow of water itself, but to conserve head and increase velocity when necessary, water from high pressure mains will be introduced in direction of water flow through three 2 x ¾-inch nozzles set on headers located near walls of basin. There will be 2 coagulation basins, each 151 x 102 feet in plan and 6.5 to 14 feet deep, with combined capacity of 3 million gallons, equivalent to 3 hours retention. Slotted stilling baffle formed of 8-inch planks, set vertically with 2-inch open

spaces and supported by "A" frame, will be placed transversely across basins 50 feet from inlet end. Filters will be of standard design except that underdrain system will be made up of 2½-inch brass laterals with 2 parallel rows of "impact orifices" set 60° apart and with 8 orifices per foot. Nominal capacity of each filter at 2 gallons per square foot per minute will be approximately 4 m.g.d., but piping and appurtenances have been designed for operation at rate of 6 m.g.d. if necessary. Equalizing clear water reservoir of 1-m.g. capacity will be located below filters. In addition there is a 10-m.g. storage reservoir in operation on distribution system. Water for filter washing will be stored in steel tank 32 feet in diameter and 23 feet high, located on high ground south of filters and enclosed in ornamental brick casing, octagonal in shape. With population of 130,000 in 1926, and system fully metered, water consumption averaged 12.5 m.g.d., or about 96 gallons per capita. Corresponding maxima were 18 m.g.d., or 135 gallons per capita.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Records Necessary to Insure Pumping Station Efficiency. CHARLES D. BURDICK. Eng. News-Rec., **102**: 963, June 13, 1929. Proper system of records justifies itself by conveying information day by day as to total efficiency and by separating different operations in station so that defective operation can be located at once and remedied. Brief details given of method employed in one large station in which all essentials of daily operation are shown upon one letter-size sheet of paper.—*R. E. Thompson.*

Installing Service Pipe in Quicksand. CHARLES P. MCGRATH. Eng. News-Rec., **102**: 963, June 13, 1929. Installation of service connections is complicated in Detroit by frequent presence of quicksand. Satisfactory method of operation under such conditions has been devised which involves use of well points on manifold connected to hand operated diaphragm suction pump. As trench is dug, well points are kept buried to prevent drawing air. By this means 3 men can install 3 inch service 30 feet long in 4 hours, as compared with 5 men in 8–10 hours by old method.—*R. E. Thompson.*

Biochemical Studies on the Occurrence of Small Quantities of Iodine and Fluorine in Organisms. V. A. MAYRHOFER and A. WASITZKY. Biochem. Z., **204**: 62–77, 1929. From Chem. Abst., **23**: 1921, April 20, 1929. Method for determination of small quantities of iodine or fluorine were tested. Etching method for fluorine described.—*R. E. Thompson.*

Effect of Aggregates on Water Ratio of Concrete. G. M. WILLIAMS. Eng. News-Rec., **103**: 71–2, 1929. Discussion of articles by F. R. MCMILLAN (cf. C. A., **23**: 3323) and reply by MCMILLAN. Williams believes that the water-cement ratio strength relation is only approximate and that disregard of aggregate factor may result in concretes inferior to those which may be produced with the same aggregate and cement content. He has found that concreates prepared by fineness modulus method of combining fine and coarse aggregate are usually inferior in strength and watertightness to mixtures of same aggregate higher in sand, all having the same cement content and con-

sistency. The latter mixtures require more water, with consequent greater water-cement value, but are stronger. As substitute for fineness modulus, or trial mixtures, Williams suggests the use of aggregate combination or gradings which give maximum weight per cubic feet. Procedure recommended for production of most economical mix of specified quality is outlined.—*R. E. Thompson* (*Courtesy Chem. Abst.*)

Anchoring a Wood-Stave Pipe on Sliding Ground. S. C. WATKINS. Eng. News-Rec., 102: 966. June 13, 1929. Water supply of Aberdeen, Wash., is conveyed to city by 28-inch wood-stave pipe line 22 miles long. When built, in 1915, about 300 feet was located across area which showed evidences of having been in motion within past century. Slight movements occurred in 1921 and 1923, and in 1925 serious movement occurred, breaking supply line in two places. Method adopted for anchoring pipe to prevent further trouble outlined briefly.—*R. E. Thompson.*

Small Town Water Works. Cont. Rec. and Eng. Rev., 43: 749–51, June 19, 1929. General discussion of details involved in development of water supply for small town.—*R. E. Thompson.*

Stony Gorge Dam Built Over Fault Subject to Settlement. J. L. SAVAGE and H. J. GAULT. Eng. News-Rec., 103: 46–51, July 11, 1929. Stony Gorge dam, recently completed in California, was erected to provide supplementary water supply for Orland irrigation project. It is a concrete structure of AMBURSEN type, 868 feet long, 125 feet high above streambed, and 142.5 feet above lowest concrete in cutoff trench. This type of dam was chosen partly because of low cost and particularly because of limited extent of failure likely to result from movement along fault line which structure crosses. Total cost of reservoir was $1,289,400 and of dam alone, $967,900. Storage capacity is 50,200 acre-feet.—*R. E. Thompson.*

Water Meters. HERBERT PRUDEN. Cont. Rec. and Eng. Rev., 43: 747–9, June 19, 1929. General discussion of value of water metering, in which it is pointed out that this is the only equitable method of water distribution. Examples of reduced consumption following installation of meters are cited.—*R. E. Thompson.*

Value of a Water Purification Laboratory to a Municipality. NORMAN J. HOWARD. Cont. Rec. and Engr. Rev., 43: 735–7, 1929. An outline and discussion of the activities of the Toronto Filtration Plant Laboratories, which were established in 1911. Research work carried out has facilitated operation of the plant, reduced operating costs, and increased the palatability of the water.—*R. E. Thompson* (*Courtesy Chem. Abst.*)

Titration of Bleaching Powder with Nitrite Solution. Z. KERTÉSZ. Z. anal. Chem., 74: 105–8, 1928. From Chem. Abst., 23: 1840, April 20, 1929. KERTÉSZ has already published a method for titrating hypochlorite with sodium nitrite (C. A. 18: 797, 2301). Method succeeds with normal bleaching

powders or those weakened by standing. If, however, sample is high in lime it is necessary to add sodium bicarbonate. In analysis of sodium or potassium hypochlorite a little boric acid should be added.—*R. E. Thompson.*

Investigation on the Corrosion of a Galvanized Iron Hot-Water Cylinder. H. F. RICHARDS. Iron and Steel Ind., 2: 45–6, 1928. From Chem. Abst., 23: 1869, April 20, 1929. A galvanized iron hot water cylinder failed by perforation after 2 years. The water was high in carbon dioxide and calcium bicarbonate and contained chloride and nitrate. Presence of basic zinc carbonate in corrosion products showed zinc to have been attacked by the hot water. Tendency for zinc to go into solution is augmented by irregularity of zinc-iron alloy layers, which cause partial exposure of alloys having different potentials causing electrolytic corrosion.—*R. E. Thompson.*

An Adaptation of Bergeim's Fecal Indole Method for the Determination of Indole in Bacterial Cultures. H. B. PIERCE and R. B. KILBORNE. J. Biol. Chem., 81: 381–7, 1929. From Chem. Abst., 23: 1924, April 20, 1929. BERGEIM'S method (C. A., 12: 45) has been adapted to estimation of indole in bacterial cultures.—*R. E. Thompson.*

The Detection of Cloramine-T and Its Differentiation from Hypochlorites. H. W. VAN URK. Chem. Weekblad, 26: 9–10, 1929. From Chem. Abst., 23: 1840, April 20, 1929. Chloramine-T is used extensively as substitute for hypochlorites. It is similar to sodium hypochlorite in many reactions, particularly in liberating iodine from potassium iodide. There are a number of reactions by which the two may be differentiated. The following are the reactions of chloramine and sodium hypochlorite, respectively, with various reagents. Thalleoquinine reaction: negative; positive, green coloring. Guaiacol tincture: negative at room temperature, decolorized by boiling; immediate decolorization. Resorcinol: green, then yellow, and red by heating; purple-red immediately. Naphthol: colorless, yellow by boiling; blue-green. Reduced indigo-carmine solution: blue; decolorizes the blue solution. Alkaline pyrogallol: reddish brown; dark reddish brown. Manganous chloride: negative; brown. Also the presence of sulfate can be ascertained in ash of chloramine. —*R. E. Thompson.*

A Study of Coliform Organisms in Samples of Certified Milk. C. H. CHALMERS. J. Hyg., 27: 294–305, 1928. From Chem. Abst., 23: 1924, April 20, 1929. Although usual presumptive test for *B. coli* was negative in case of 32 certified milk samples, upon culturing these same samples on bile salt agar, all plates proved positive and 268 coliform bacteria were isolated. Of these, 65.7 per cent were true *B. coli* and 18.6 per cent fell in the X and Y groups of STEWART. The presumptive test cannot be relied upon to give true indication of presence of coliform bacilli in milk. Inaccuracy is attributed in part to faulty construction of DURHAMS' fermentation tubes which fail to ensure collection of the gas produced.—*R. E. Thompson.*

The Construction of Various New Steam-Regulating Devices for Pipe Lines. H. WINKELMANN. Apparatebau, 41: 40–2, 1929. From Chem. Abst., 23: 2074, May 10, 1929. Descriptions of Borsig valves.—*R. E. Thompson.*

Two New Methods for the Determination of Phenol in Waste Liquors. H. DEHE. Chem.-Ztg., 52: 983–5, 1928. From Chem. Abst., 23: 1841, April 20, 1929. *Method 1.* To 200 cc. of well-shaken waste liquor add 10 cc. saturated zinc acetate solution, 40 cc. 5 per cent silver nitrate solution (or more if necessary) and 10 cc. 1:3 sulfuric acid and shake for 3–5 hours. Filter, acidify filtrate with dilute sulfuric acid, add few drops of hydrogen peroxide and distil with steam until distillate no longer gives positive test for phenol with Millon's reagent and nitric acid. Make the distillate alkaline with sodium hydroxide and evaporate. Transfer residue to 500-cc. volumetric flask and fill to mark. Mix 10 cc. of this solution (or more if phenolic content is low), with hydrogen peroxide and warm to 50–60°. Add 15 cc. of 0.1 N iodine solution (more if phenolic content is high), let cool, acidify with dilute sulfuric acid and titrate back with 0.1 N thiosulfate. *Method 2.* Mix 55–60 cc. of the solution (in the 500-cc. flask) with knife-point full of baryta. Shake and allow to stand few minutes. Filter and mix 25 cc. of filtrate with about 10 drops of dilute sulfuric acid. Filter off the barium sulfate and wash filter 2–3 times with least possible amount of carbon dioxide-free water. Add exactly 0.2 cc. of 0.1 per cent alizarin yellow solution, and first with strong sodium hydroxide and dilute sulfuric acid and then with 0.1 N alkali and acid, bring to pH 11.04 with aid of suitable buffer solution. Then add about 0.1 cc. 1 per cent phenolphthalein and titrate with 0.1 N sulfuric acid to pH 8.4, again using a buffer. From the number of cc. 0.1 N acid used, the correction for pure water is subtracted. One cc. 0.1 N acid is equivalent to 9.4 milligrams phenol. Under normal conditions the number of cc. of 0.1 N acid used multiplied by the factor 2.09 gives grams of phenol per liter.—*R. E. Thompson.*

Potable Water Supply. E. FOURNIER. L'Eau, 21: 179–80, 1928. From Chem. Abst., 23: 1972, April 20, 1929. Ground waters in limestone areas should be subject of closest scrutiny because of danger of remote contamination. Use of fluorescein in detection of polluted sources is advocated.—*R. E. Thompson.*

The Provincial Department of Health's Relation to the Water Works Engineer. A. E. BERRY. Cont. Rec. and Engr. Rev., 43: 733–4, 1929. A brief discussion of the activities of the Ontario Provincial Department of Health in the field of water supply. Authority to issue mandatory orders to carry out water works or sewerage programs has been exercised on several occasions. Of the 270 water systems in operation in Ontario, 184 are supplied from surface sources and 86 from wells and springs. Seventy-five per cent of the water used for domestic purposes is chlorinated. The standard requirement for Cl_2 dosage is residual of 0.1 to 0.3 p.p.m. free Cl_2 after 15 minutes contact, depending on local conditions. There are now 21 activated sludge plants in operation in Ontario municipalities and 10 in institutions.—*R. E. Thompson* (*Courtesy Chem. Abst.*)

The Application of pH Control. W. A. TAYLOR. J. Chem. Education, 6: 36–43, 1929; cf. C.A., 22: 4192. From Chem. Abst., 23: 1969, April 20, 1929. Control of pH is discussed in relation to a number of processes, including water purification, corrosion, etc.—*R. E. Thompson.*

The Diurnal Variation of the Gaseous Constituents of River Waters. IV. ROGER W. BUTCHER, FREDERICK T. K. PENTELOW and JAMES W. A. WOODLEY. Biochem. J., 22: 1478–89, 1928; cf. C.A., 23: 458. From Chem. Abst., 23: 1972, April 20, 1929. Factors governing dissolved oxygen content of river water are the time of day in connection with processes of photosynthesis and respiration; season of year; prevailing actinic conditions; physical characteristics of river; temperature variations; solution of oxygen from air; and degree and nature of pollution. Throughout the year the pH curves were very similar in structure to those of saturation of oxygen. Concentration of carbon dioxide is roughly inversely proportional to that of oxygen.—*R. E. Thompson.*

Corrosive Action of Water Corrected by Hydrated Lime Treatment. E. SHERMAN CHASE. Eng. News-Rec., 103: 70, 1929. The water supply of Falmouth, Mass., pumped from a natural pond, is practically free of mineral constituents, CO_2, Fe, and color, supersaturated with dissolved O_2, and highly corrosive. The water delivered to the consumers was discolored, particularly during the winter months when the consumption was low and the water remained in contact with the pipes for a considerable period. Laboratory tests indicated that the corrosiveness could be corrected more efficiently with $Ca(OH)_2$ than with Na_2CO_3 or Na_2SiO_3. The 83 pounds $Ca(OH)_2$ required per million gallons will increase the hardness about 10 p.p.m. The necessary equipment is being installed.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

The Sterilization of Sea Water by Ozone. Application of the Method to Purification of Contaminated. Shellfish. H. VIOLLE. Rev. hyg. méd. prév., 51: 42–6, 1929. From Chem. Abst., 23: 1972, April 20, 1929. Sea water, seeded heavily with *B. typhosus*, *B. coli*, *B. proteus*, *V. cholerae*, *B. pyocyaneus* and *B. dysenteriae* in wood flasks became sterile after 7–8 minutes of ozonization. To prove that the sea water contained no bactericidal substance, ozone was bubbled through the water for 15 minutes and after aëration for few seconds, bacterial suspensions were added. After 18 hours incubation all showed active growth. Laboratory experiments were made using contaminated oysters, ozone concentration being twice that necessary to sterilize sea water. Water was changed twice daily. The oysters were sterile after 5–6 days. Fifteen days is considered maximum time necessary to purify oysters with ozone. Appearance, vitality and flavor of ozone-treated oysters were normal. —*R. E. Thompson.*

Adsorption of Carbonic Acid by Iron Hydroxide. J. TILLMANS, P. HIRSCH and K. SCHILLING. Kolloid-Z., 47: 98–101, 1929; cf. C. A., 23: 1973. From Chem. Abst., 23: 2086, May 10, 1929. Corrosion experiments led to belief that dissolved carbonic acid was adsorbed by ferric hydroxide. This was found to be the case. Probable mechanism of relation between free and bound carbonic acid described.—*R. E. Thompson.*

Influence of Certain Water Conditions, Especially Dissolved Gases, on Trout. JAMES S. GUTSELL. Ecology, 1: 77–96, 1929. From Chem. Abst., 23: 1960, April 20, 1929. Experimental data on brook, brown, and rainbow trout ob-

tained at Cornell University hatchery showed that marked increase in percentage of carbon dioxide and decrease in oxygen content in spring and brook water took place as warm season advanced. This is attributed to increased activity of soil bacteria. If oxygen content fell below approximately 1.3 p.p.m., death always occurred. The pH and temperature of the water were shown not to vary greatly and were not considered vital factors. Trout gradually accustomed to reduced oxygen survived oxygen contents considerably below those which were fatal to trout from well oxygenated water. By means of numerous transfer experiments from water rich in oxygen to water poor in oxygen, trout were asphyxiated in every case when oxygen content fell below 1.3 p.p.m., Partial asphyxiation and sluggishness often occurred at oxygen concentrations of from 2.5 to 1.3 p.p.m., though some fish survived several days. Above 2.5 p.p.m., trout were usually normal. If partially asphyxiated trout were removed from low oxygen water to oxygenated water, recovery occurred in as low oxygen concentrations as 2.67 p.p.m. Limited data indicate that brook trout are able to survive lower oxygen tensions than brown or rainbow trout. Carbon dioxide up to 28 p.p.m. was not markedly harmful and in amounts up to 39 p.p.m. did not increase the ill effects of reduced oxygen tension. Trout inhabit both acidic and basic waters and, providing the oxygen content is sufficient, are hardy to considerable variation in pH.—*R. E. Thompson.*

Annual Report of the Agricultural Chemist. P. E. LANDER. Rept. Operations Dept. Agr. Punjab, Year Ending June 30, 1926, I, pt. 2, 47–66, 1928. From Chem. Abst., 23: 1979, April 20, 1929. Examination of Lyallpur city drinking water showed a high bacterial content resulting from too great a flow of water through filter beds. Higher counts were obtained by plating on ordinary nutrient agar than on synthetic medium.—*R. E. Thompson.*

A Non-Chemical Method for the Prevention of Scale Accumulation in Boilers, Diesel Jackets, and Water Circulating Systems in General. A. T. RIDOUT. Domestic Eng. (London), 48: 163–5, 1928. From Chem. Abst., 23: 1973, April 20, 1928. System described utilizes colloids in feed water. Starch in colloidal form from linseed without extraction of oil by steam treatment of seed in cast steel receptacle with perforated canister. The carbohydrates are infused in colloidal condition. Oil is not extracted because no crushing effect is brought about. Starches are extracted in about 24 hours and 1 pound of seed is sufficient for 2000 gallons of feed water. Cost of upkeep is low. Cost of installation and difference in space occupied as compared with a water softener are advantages. Acid attack of boiler and galvanic action have been arrested. It is claimed that salt water feed is possbile. Bare plates are impossible, as colloid is destroyed at junction of water and plates. This results in formation of thin film of protective scale, which is easily removable.—*R. E. Thompson.*

Concentration Control Provides Good Quality Boiler Feed Water. LUCIUS A. FRITZE and ELWOOD W. SCARRIT. Power, 69: 346–9, 1929. From Chem. Abst., 23: 1973, April 20, 1929. Boiler water is circulated through settling tank which may be inside or outside boiler. Flocculent solids rise; heavy,

scale-forming solids settle, and clarified water is returned to boiler from near center of tank. From 25 to 150 per cent of hourly evaporation may be treated, proportion depending on conditions.—*R. E. Thompson.*

The Chemical Control of Boiler Plant. C. N. RIDLEY. Ind. Management, 15: 360–1, 1928. From Chem. Abst., 23: 2231, May 10, 1929. Discussion of feed water treatment and problems relating to combustion.—*R. E. Thompson.*

Some Problems in Hydro-Geology. EDGAR MORTON. Water and Water Engineering, 31: 372, 564–568, December 20, 1929, and 32: 373, 12–16 January 20, 1930, Run-off from a catchment area is influenced by: (1) relative absorption and fissured character of the rocks, (2) rock structure, (3) incidence of superficial deposits, (4) topography, (5) vegetation, both amount and type, (6) distribution of rainfall as to space. All these variables may influence available yield and computed size of storage reservoirs. Both rainfall and run-off should be considered in any specific case. Author is preparing a series of maps which will give for each water-bearing formation its subterranean extent, depth below surface, variations in thickness and general form. These will be available as a basis for estimation and allocation of underground waters. Percolation is closely related to underground water inasmuch as for any given area the abstraction of the latter should not exceed the rainfall percolation. Tabulations are given of experimentally obtained percolation through various types of soil, subsoil, and rock. Some general principles are drawn from these data. The disadvantages and the natural difficulties met with in use of the percolation gauge lead to the conclusion that yields from pervious areas must be otherwise determined. A graphical method is suggested for which following data are needed: (1) long period records of fluctuations in the water-table, from which should be determined: (*a*) the absolute minimum level, (*b*) the average level, (*c*) the variations in level each year, expressed as percentages of the average, (2) the distribution, thickness, and form of the water-bearing strata, especially in relation to the contiguous impervious formations, (3) all information obtainable from exposures, published records, and preserved cores of wells and boreholes, concerning texture and structure of the pervious strata. The geological facts in (2) can then be put into map form with horizontal sections and the information under (1) placed on those maps. A plea is made for publication of available information on ground water and for its extension by systematic records.—*Arthur P. Miller.*

Skegness, England, Water Tower. Anon. Water and Water Engineering, 32: 373, 8, January 20, 1930. After elaborate tests had been made to determine safe load which sub-soil would bear and modification of the design to reduce maximum load, a water tower with capacity of 200,000 gallons standing 100 feet above ground level at Skegness was found to have developed a tilt which necessitated remedial action. To return the tower to a vertical position and stabilize it, a half circle of interlocking steel sheet piles was driven around it to a depth of 32 feet on the half circumference representing the low side of the base. Then some 14 borings 12 inches in diameter were driven around the high side of the base, which was also loaded with sand bags and

earth to induce a movement. This was obtained and was controlled by "shelling" from the particular borings towards which movement was desired. After it had reached the vertical, which required a period of two months, it was maintained upright by plugging the boreholes from the surface.—*Arthur P. Miller.*

The New Waterworks for Ashborne, England. Anon. Water and Water Engineering, 32: 373, 9–11, January 20, 1930. Ashborne, Derbyshire, in 1926 drilled an exploratory borehole into the new red sandstone for increased water supply. Result justified development of the site and in 1927 two wells, 32 feet apart and 23 inches in diameter, were sunk to depth of 300 feet. The article describes the borehold pumps installed and the pumping station and gives complete data on the tests of the two wells. Fuel for the oil engines is stored in an underground tank holding about three months' supply and is pumped by a small hand pump to the fuel service tank. For the bearings of each pump there is a water filter in the corner of the engine room and to assist in starting the engines, a pair of air receivers charged with compressed air. The whole plant is in duplicate.—*Arthur P. Miller.*

Artesian Well Supplies in New South Wales. Anon. Water and Water Engineering, 32: 373, 11, January 20, 1930. A report at the fifth inter-State conference on artesian wells in New South Wales in 1928 states that of the 233 bores which have been gauged periodically from 1914 to 1928, the daily flow has decreased almost 40 per cent for the entire period, or an annual average of little over 3 per cent. Indications are that the head in the New South Wales section of the Australian basin is still decreasing. Under the scheme to supply settlers with water, a total of 2432 bores were constructed up to the middle of 1928 and of these only 17 per cent were failures.—*Arthur P. Miller.*

Athens Water Supply. Anon. Water and Water Engineering, 32: 373, 22–23, January 20, 1930. A dam is being constructed on the Harada and Varneva rivers in the gorges of Marathon to impound water for the supply of Athens, the Piraeus, and environs. The dam will be 270 meters long and 49½ meters high. The retaining reservoir will hold 27,000,000 cubic meters, forming a lake 2¼ square kilometers in area. The dam will be completely faced with white marble.—*Arthur P. Miller.*

Barlow Filtration Works. Chesterfield, England, Rural District Council. Anon. Water and Water Engineering, 32: 374, 57–58, February 20, 1930. These works have been built to meet the need for additional water supply. They comprise five Candy pressure filters each having an automatic slow-start mechanism which brings it into operation just after the filter has been washed and gradually increases the rate of flow. Each filter is also controlled by a module, or rate controller. Air and reverse flow of water are used for washing. Wash water from the filters, after settlement in a tank of the heavier suspended matter, is decanted off into the river. The chemical plant is in duplicate and comprises mixing tanks for the necessary chemicals.—*Arthur P. Miller.*

The Relative Coloring Power of Leaves of the Commoner British Trees and Shrubs. B. A. ADAMS. Water and Water Engineering, 32: 374, 58–61, February 20, 1930. Leaves, both green and dead, were allowed to dry in a warm dry shed. Infusions were made of two grams of broken dead leaves in 400 cc. of colorless soft deep well water. These were stored in a cool room and agitated once a day. Colors were determined after 24 hours and 3, 7, 14, 21, and 28 days. The "heated" colors were gotten from similar infusions in flasks surrounded by boiling water for one hour. To measure color, the samples were matched against a dilute alcoholic solution of Bismarck brown in Nessler tubes. The writer discusses the experiments briefly and summarizes the principal points as follows: (1) the leaves of certain trees and shrubs when added to water produce high colors and these should therefore be avoided in waterworks planting: on the other hand, certain others should be used, because they do not produce high colors; (2) certain listed trees whose leaves color water rapidly should be unconditionally avoided: other trees are to be avoided where possible: others, again, may be utilized, but are not preferred; while others, which color water only slightly and then only after a considerable period of time, are preferred, including cypress, alder, holly, gorse, bay, larch, Scotch pine, stone pine, spruce, and fir.—*Arthur P. Miller.*

Seasonal Variation in Salinity of Nile Water in the Aswan Reservoir and at Rodah (Giza). R. ALADJEM. Ministry of Agriculture, Egypt. Technical and Scientific Service. Bull. 81: 1928. Government Press, Cairo, 24 pp., 5 plates. Analysis of samples of Nile Water at Rodah Bridge were published in Bull. 69. Samples were taken at Aswan under the same conditions, i.e., weekly for two years at 2 metres below the surface and at the same spot. Tables are given of the means of the results obtained and of the percentage of dissolved solids at both places, and a special table of R. L. readings at Aswan, gauge readings at Halfa, Aswan Reservoir contents and the lag in days from Aswan to the Delta Barrage. Graphs are also given showing the comparative curves in the two cases for total solid contents, bicarbonates, chlorine as NaCl, and the amount of discharge at Aswan Dam, and at the Delta Barrage. The salinity of the water rises from 110–120 parts per million of total dissolved solids at the end of October to 200–220 parts per million about the end of April, the increase being due mainly to overflow of waterings and subsoil water. Alkalinity during low Nile period is due to alkaline carbonates and bicarbonates and during the rest of the year is partly due to silicates and bisilicates.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Measurements of Turbidity; Nephelometry and Interferometry for Water. Examination. E. NAUMANN. Z. angew. Chem., 1929, 42: 22, 626. Two new processes for the measurement of turbidity in water are (1) measurement of the absorption of light, and (2) estimation of the intensity of the "TYNDALL light." The absorption of light is dependent on the degree of dispersion, the natural colour of the water, and the colour of the substance causing turbidity. In the TYNDALL method the sizes of the particles and their relation to the wavelength of the light play a part. The conditions under which some of these fac-

tors might be disregarded, or eliminated, was discussed. Good results are often obtained with the best-known forms of apparatus but there is no general and absolute agreement. Interferometer measurements, especially in conjunction with the results of estimation of conductivity and residue on evaporation, Tyndallometry, and ultrafiltration, are a valuable aid towards finding a relative measure for the colloids dissolved in water.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Calculation of Permanganate Demand and Chlorine Number in Waters containing much Iron. W. AUSTEN. Z. Angew. Chem., 1929, 42: 22, 626. In dealing with the estimation of chlorine number and permanganate demand, the text-books pay too little attention to water containing iron. To get a reliable value for permanganate demand, ferrous salts must first be separated by titration with permanganate in the cold, and accurate methods are not available. In connection with EGGER'S experiments on chlorine number, a workable method for permanganate estimation was investigated. Ferrous iron was oxidised with permanganate in acid solution, the solution neutralised, and then boiled in alkaline solution with N/50 hypochlorite. After addition of 10 per cent potassium iodide solution, the cooled liquid was led into a graduated measuring cylinder, the hydroxide settled, and the unused hypochlorite determined. In waters with iron in organic combination, the difficulties arising from fecal impurities are not entirely removed.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Determination of the Hardness of Water by means of a Soap Solution. G. BRUHNS. Chem. Ztg., 1929, 48: 469. The author describes a method for determining both the lime and magnesia hardness of a water by a single test in one water sample. He found on adding soap solution, prepared as described by BOUTRON and BOUDET, very slowly to a hard water that the persistent lather formed at one point disappeared on the addition of more soap solution, and that a second lather formed later, which remained stable even if more solution was added. Investigation showed that the first end point is given when all the lime is combined and the second, when all the magnesia is combined. In making the test, there is danger of missing the end point for the lime, but this may be avoided if the following method is carried out. A 100 cc. water sample is first tested for free carbon dioxide, by means of 0.1 N soda solution using phenolphthalein as indicator. This neutralised sample is then shaken with a small quantity of soap solution, equivalent to about 5° hardness (French), after which the solution is added drop by drop. On adding the soap solution a red colour is produced. On nearing the end point for the lime hardness the red colour turns to a pale rose, and the exact point is indicated by formation of a lather. The red colour reappears on adding more soap solution, and the end point for the magnesia hardness is shown by the appearance of the second persistent lather. If the water is very hard, it should be diluted with distilled water, freed from carbon dioxide, before making the test.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Olszewski-Keyl Apparatus for Taking Water Samples. OLSZEWSKI. Chem. Ztg., 1929, 53: 149; Wass. u. Abwass., 1929, 26: 11. A short description is given of the apparatus for taking water samples, made by HUGO KEYL of Dresden. It is similar to the apparatus invented by SPITTA and IMHOFF, and is used for obtaining samples from rivers, lakes, and reservoirs for chemical and bacteriological analysis. By doing away with the use of taps, the flasks are all filled within one minute.—*M. H. Coblentz (Courtesy of the Department Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Fauna and Flora of the Zuider Sea. A Contribution to the Biology of Brackish Waters. H. C. REDEKE. IV Congresso Internazionale di limnologia teorica ed applicata. Settembre 1927. Societa tipografica A. Manuzio, Rome 1928. The Zuider Sea is one of the most interesting brackish water areas in Western Europe. This inland sea, covering about 145,000 hectares, is slowly changing to a fresh-water lake. The Netherlands Zoological Society is investigating the changes in conditions and their effect on the flora and fauna. The water within a certain short radius near the mouth of the river is oligohaline, with a salt content up to 10 p.p.m. of chlorine; the greater part of the sea is mesohaline, with a salt content from 10 to 100 p.p.m., and in the north the water gradually merges into sea water. A few fresh-water species live in the oligohaline zone. In the polyhaline zone, the majority of the species are essentially maritime, and dwarf forms of the same species are found in the brackish zone. Among the autochthonous brackish water fauna and flora are a number of endemic species as well as species similar to those found elsewhere under similar conditions. The number of species is very small in proportion to the abundance of individuals. It is hoped that the investigation will throw some light on the interdependence of the various components of the life of brackish water and also the intermediate fauna and flora between the brackish and freshwater facies.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Wintering of Water Organisms in Ice and in Frozen Soil. S. A. SERNOV. IV. Congresso Internazionale di limnologia teorica ed applicata. Settembre 1927. Societa Tipografica A. Manuzio, Rome 1928. The ice from a number of ponds and the frozen sludge from several dried-up fish tanks near Moscow were found to contain a number of living organisms, both animals and plants. The author suggests the name "Pagon," from the Greek word meaning "from ice," corresponding to the term plankton, for this class of organisms. In the melted ice from the surface of two ponds were found 117 species, of which 7 were plants and 110, invertebrates. The temperature of the layer of ice, protected from below by the water and from above by snow, remains constant at 0°C., and a number of organisms are evidently able to live under these conditions. The Pagon is a selected fauna, and not simply the organisms found in the water in the autumn.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

The Microscopic Flora of Alkaline and Calcareous Thermal Waters containing Sulphur. J. and M. L. DUFRENOY. IV. Congresso Internazionale di limnologia teorica ed applicata. Settembre 1927. Societa Tipografica A. Manuzio. Rome 1928. Sulphur bacteria principally represented by the species *Thiothrix*, are found abundantly both in hot calcareous sulphur springs, e.g., Aix-les-Bains, and also in hot alkaline sulphur springs in the Alps and the Pyrenees, e.g., Luchon, Barèges, Cauterets. The activity of the bacteria reduces sulphates, and more especially iron sulphates, present in the water, to hydrogen sulphide. Barègines, ball-like formations composed of microörganisms, cover the surface of the reservoirs in which the water from the springs is stored. The upper surface of the barègines is covered with a network of *Thiothrix* colonies, while the under surface is the home of colonies of anaërobic sulphate-reducing bacteria, protected from the oxygen of the air by the aërobic *Thiothrix*. The gelatinous substance enclosing the colonies of bacteria, is a hydrogel, giving the colour reaction for pectic substances, and having the power to absorb either the red of ruthenium or safranin from very dilute solutions. Barègines are are found at the feebly alkaline springs of Source d'Alun and Aix-les-Bains, and at alkaline sulphur springs of which the pH varies from 9 at Luchon to 10.3 at Barèges and Source Tambour.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Report on the Fauna of the Estuaries of the River Tamar and the River Lynher. E. PERCIVAL. J. Marine Biol. Assoc., **16**: 81, 1929. These two rivers flow into Plymouth Sound, England. Sea water flows 19 miles up the Tamar and about 8 miles up the Lynher. Mud-banks and flats slope gradually into the river channel, and plant detritus deposited on the wide flats on the concave sides of river bends provides nourishment for a large fauna. The salinity of the river water at different stages of the tide was measured at a number of localities. A curve of the high water salinity of the Tamar is plotted, showing the localities where the determinations were made. The distribution of the marine plankton also indicates the movements of the sea water. The species collected in the two rivers fall into four groups, according to their distribution; (1) plankton and benthos coming in from the sea, intolerant of changing conditions and not found further than 5 miles upstream, (2) fauna coming in from the sea and persisting 11 miles upstream, (3) brackish water species, replacing the marine species at a point about 10 miles upstream, (4) freshwater species. The greatest number of species belong to the first group, while only two are included in group (4). The most interesting points in the occurrence and distribution of the fauna are noted under the different animal groups, arranged systematically, and a complete faunistic list is given with the habitat and name of the locality or localities where the collection was made.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Extraction of Gases from Boiler Feed Water. W. TOLLER. Vom Wasser. Ver. Deutscher Chemiker. Berlin, 1927, 1: 84. The action of gases on the

boiler inner surface is explained as follows: The hydrogen-ion concentration increases under boiler conditions of temperature and pressure, the acid action dissolves ferrous iron from boiler walls until equilibrium required by existing hydrogen-ion concentration is reached. This concentration, and therefore amount of iron dissolved, is increased by presence of carbonic acid. Oxygen present oxidizes ferrous iron to ferric, which precipitates, and further iron is dissolved to regain equilibrium. Differences in potential between various parts of surface also increase tendency to corrosion. Different methods of preventing action of the gases are considered, such as maintenance of a certain degree of alkalinity, addition of such salts as chromates, applying of protective coatings either organic or metallic, application of direct or alternating current to nullify effect of differences in potential. Conclusion is reached that the only satisfactory method is removal of the gases by mechanical or chemical means. Different mechanical means are discussed and the common disadvantage pointed out that after freeing from gases water has to be kept from all possible contact with air on its way to boiler. Chemical methods of filtration through iron filings or turnings, or the newer method of filtration through finely turned steel, have the advantage that filtration can be carried out in the pressure pipe leading into boiler. Filtration through charcoal would be ideal if the charcoal could be easily regenerated after use. Removal of oxygen by addition of sodium sulphite is not recommended because of difficulty of judging the necessary quantity when water composition is variable and because dissolved salts are carried into boiler.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Importance of the Removal of Dissolved Organic Substances from Boiler Feed Water. A. SPLITTGERBER, Z. angew. Chem., 42: 22, 626, 1929. The partly colloidal organic substances in solution in many boiler feed waters increase the solubility of calcium carbonate, so that satisfactory softening is often not possible. The organic substances become concentrated in the boiler and a residual hardness far above the limit of 2° results. Removal of organic substances has for a long time been effected by flocculation with aluminium (keeping a pH value of 6) and subsequent softening by means of chemicals at a pH value of over 7.5.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

Modern Principles for the Judgment of Boiler Feed Water. A. SPLITTGERBER. Vom Wasser. Ver. deutscher Chemiker. Berlin, 1927. 1: 62. Author deals first with necessity for uniform methods of examination of boiler water and use of same standards, so that results from different places may be directly comparable. He sets out a scheme for tabulation of results of water analyses and observation. The different softening processes, and use of knowledge of chemical composition of water in choice of process to be adopted are discussed. The article then deals in some detail with the supervision of chemical composition of purified water and treatment of constituents liable to prove harm-

ful, including softening chemicals and dissolved gases, and the treatment and re-use of condense-water.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

The Preparation of Boiler Feed Waters with Special Reference to High Pressure Boilers. A. SPLITTGERBER. Vom. Wasser. Ver. deutscher Chemiker, Berlin, 1928, 2: 92. Author has prepared general summary of the literature on this subject and gives account of present state of knowledge and of conclusions so far reached. He deals first with the evaporation of boiler feed, pointing out that in most cases previous preparation of raw water is necessary. Carbonate hardness must be removed, leaving only sufficient to counteract effect of free acid present. This is usually done by treatment with hydrochloric acid. Sulphate hardness and magnesia must also be treated. In treatment by distillation the gases must be as far as possible extracted from the feed water, which necessitates complete protection against any further contact with air. The acid action of this gas-free distilled water on iron has then to be prevented by addition of alkalis. If the boiler drum is seamless, the danger is not so great, but in a rivetted drum caustic soda may collect in the seams and reach a high concentration. A sulphate content standing in a definite relationship (which varies with the pressure) to carbonate content allows the more easily soluble sulphate to act as a protection. The same results can be obtained by the addition of smaller quantities of alkaline phosphates and it has been found that trisodium phosphate also completely prevents formation of scale. It appears however that phosphates cause increased foaming and priming. In certain cases it is necessary to supply a chemically prepared water for boilers. The literature on the subjects of the concentration of salts, chemical softening, and the formation of silicic acid and silicate scale under high pressure is discussed. It appears that silicic acid can be partly avoided by sufficient excess of alkali; but further investigation is necessary. At present the only preventative, or at least palliative of scale formation is softening, which is best accomplished by the Permutit process. This, however, by enriching the sodium bicarbonate content leads to formation of caustic soda and carbonic acid in the boiler. Treatment with acid is therefore adopted. A combination of German and American experience suggests the following method. The greater part of the hardness is removed by addition of lime and soda; caustic alkalinity (shown by phenolphthalein) is neutralised by acid until bicarbonate alkalinity (which is not harmful to the Permutit process) can be shown by methyl orange test; the water is cooled and remaining hardness removed by Permutit process. Oils and fats can be removed in several ways, of which the most successful appear to be treatment of the steam by surface attraction and de-oiling by chemical precipitation with aluminum sulphate and alkali and subsequent filtration. An account of experiences with different specially designed boilers for very high pressure work closes the article.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Board, Summary of Current Literature*).

ABSTRACTS SUB-COMMITTEE NO. 9

JOINT RESEARCH COMMITTEE ON BOILER FEEDWATER STUDIES

Safety in Boiler Plant. Power, 70: 26, December 24, 1929, p. 1015. Summary of record for 40 years (1880–1919) shows that during that period there were 14,281 explosions, in which 10,638 lives were lost and 17,085 persons injured; causes of accidents; high-pressure plants require special precautions; Monday explosions; training necessary to insure safety.

Compound, Boiler. U. S. Navy Dept. Specification No. 13C3e, December 2, 1929, 2 pp. General specifications covering grade, material and workmanship, general and detail requirements; method of inspection, tests, packing and marking. Bibliography.

Corrosion Fatigue and Explanation of Boiler-Plate Failure. H. C. DINGER. Power, 71: 4, January 28, 1930, pp. 133–134. Various theories have been advanced for initial cause of boiler-plate failures, particularly those manifested as cracks after considerable period of service where stress has never exceeded or approached elastic limit; those theories usually try to visualize some special condition.

Keeping Heating Surfaces Clean for Increasing Efficiency of Boiler Plants (Sauberhaltung der Heizflaechen zur Hebung der Wirtschaftlichkeit von Dampfkesselanlagen). H. SCHLICKE. Waerme (Berlin), 52: 51, December 21, 1929, pp. 979–982. Feedwater softening for prevention of boiler scale; removal of oxygen and carbon dioxide from feedwater; prevention of scale on heating surfaces coming in contact with flame.

Boiler Explosion Inquiries. Engineering (London), 128: 3336, December 20, 1929, p. 826. Summaries of reports of investigations conducted by Board of Trade officials; failure of steel feedwater-delivery pipe; bursting of old egg-ended cylindrical boiler.

Continuous Boiler Blowdown. E. K. BLANNING. Power, 71: 3, January 21, 1930, pp. 95–97, 4 figs. Discussion based on 48-day tests of Kansas City plant of Armour and Company which shows $7180 yearly saving on fuel gas; isometric diagram of continuous blowdown system.

Rational Measurement Coefficient for Water Analysis (Rationale Messzahl fuer die Wasseranalyse). A. SULFRIAN. Waerme (Berlin), 52: 47, November 23, 1929, pp. 867–869, 1 fig. Instead of coefficient of hardness which, it is claimed, is on arbitrary basis, "milli" standard unit is propcsed, which, author states, has scientific basis; relations between milli-unit, degrees of German hardness, milligram substance per liter, and standard solution are shown in alignment chart.

Water for Steam Generation. C. DICK. Universal Eng., 51: 1, January 1930, pp. 32–34. Discussion of molecular composition of calcium, magnesium, and sodium salts usually found in boiler feedwater.

Alignment Chart for Calculating Alkalinity in Boiler Water. E. A. WADE. Power, 70: 27, December 31, 1929, p. 1041. As indicated.

Boiler Feed and Cooling Pond Water Treatment. A. C. EMBSHOFF. Power Plant Eng., 34: 5, March 1, 1930, pp. 266–267. Lime and alum, recarbonation, filtering, and zeolite treatment, in proper combination, prove economical in municipal plant; table giving analysis of water supply; other methods considered ideal for requirements.

Combination Treatment Methods Prevail. Power Plant Eng., 33: 24, December 15, 1929, pp. 1347–1349, 1 fig. Practice in boiler-water treatment embraces large variety of methods each adapted to prevailing individual conditions; use of evaporators increases; lower velocity reduces carry-over; zeolite treatment serves evaporators; employment of deaërating heaters increases; table exemplifying feed-water treatment and heating in central power stations.

Development of a High Pressure System for Boiler Water Conditioning. A. A. MARKSON. Combustion, 1: 10, April 1930, pp. 27–30 and 34, 3 figs. Description of high-pressure system, using HALL phosphate treatment, as developed at Kip's Bay Station of New York Steam Corporation and later installed at Station A, operated by same company; theoretical aspects of work are fully discussed, and equipment and operation described in some detail; definite conclusions offered based on nearly 12 months experience. Abstract of paper presented before American Society Mechanical Engineers.

Feedwater Purification Systems Demand Expert Control. S. T. POWELL. Power, 71: 11, March 18, 1930, pp. 446–447, 4 figs. Discussion of scientific methods pertaining to purification of boiler feed water; article shows definitely dollars and cents value of competent control of feed-water purification.

Feedwater Treatment. Power Plant Eng., 34: 1, January 1, 1930, pp. 38. Table giving some of common impurities found in feedwater and general types of treatment.

Is Soft Water the Criterion of Scale Prevention? A. R. MOBERG and E. M. PARTRIDGE. Combustion, 1: 9, March, 1930, pp. 21–23, 1 fig. Authors present theories together with conclusions concerning correct feedwater treatment which are supported by actual test results and other data.

Mechanical Problems of Boiler Water Treatment. Power Plant Eng., 34, 9, May 1, 1930, pp. 491–494, 4 figs. Discussion of 1500 test samples which show effect of boiler circulation on blowdown, deconcentration, and concentration problems; boiler operated satisfactorily with total solid concentration of around 1100 grains per gallon; curves illustrating test results.

Modern Feed-Water Treatments Are of Four Kinds. L. W. HAYWARD. Power, 70: 24, December 10, 1929, p. 936. Practical discussion of four methods of feedwater treatment.

Phosphate Treatment of Boiler Water. E. P. PRICE, Combustion, 1: 7, January 1930, pp. 35–38, 5 figs. Brief review of principal difficulties incident to rapid changes in operating practice and results of experiments conducted on strictly commercial bases extending over period of two and one-half years; description of feedwater testing apparatus.

Preparation of Boiler Feedwater (Die Aufbereitung des Kesselspeisewassers). R. STUMPER. Archiv fuer Waermewirtschaft (Berlin), 11: 3, March 1930, pp. 75–80, 4 figs. Softening of feedwater; thermal softening; purification by evaporation; chemical softening; lime-soda process; Permutit process; comparison of different softening processes; degasification.

Prevention of Scaling by Water Treatment Inside of Boilers (La prévention des incrustations par le traitement de l'eau a l'intérieur des chaudières). Génie Civil (Paris), 96: 2, January 11, 1930, pp. 43–44. Internal treatment methods based on chemical and physical reactions; precautions to be taken and limitations in use of internal treatment are briefly outlined.

Purification of Water for Steam Boilers (Purification del agua para calderas de vapor). H. H. WILKINSON. Ingenieria International, 17: 12, December 1929, pp. 616–618, 5 figs. Purification systems; hardness of water and how to eliminate it; zeolite as most economical and practical purifier.

Water for Steam Generation. C. DICK. Universal Engr., 50: 6, December 1929, pp. 21–23. Discussion of importance of feedwater treatment for steam generation; definition of chemical terms; chemical reactions in feedwater treatment.

Experience With Zeolite and Acid at Beacon St. Plant. J. H. WALKER and L. F. COLLINS. Power, 71: 14, April 8, 1930, pp. 552–555, 3 figs. Discussion of operation of zeolite feedwater treating system installed in plant of Detroit Edison Co., which has been in operation for 3½ years; diagram of feedwater system; table of water analyses at various points in cycle; table giving annual operating cost of feedwater treating system.

Some Notes on Water Softening. J. GORDON. Gas World (Lond.), 92: 2370, January 4, 1930, pp. 10–13, (coking section), 1 fig. Power plant at Lambton consists of six Lancashire boilers, each 30 feet long by 8 feet in diameter; four are heated by gas and waste heat from ovens and two are hand-fired; total evaporation of water per day is about 50,000 gal.; boiler water tests; softening inside boiler; chemistry of softening by caustic soda; lime and soda ash treatment; amount of sludge and of evaporation. Paper read before Coke Oven Managers' Assn.

Water Softening Practice in Great Britain. D. BROWNLIE. Combustion, 1: 7, January 1930, pp. 39–44, 10 figs. Description of improved types of reagent feed gear and of combined lime and soda ash and base-exchange treatment are chief features for boiler feedwater; description of typical installations of four systems that are used most intensively.

Distillation of Completely Dried Lignites with Regard to Tar Recovery and Distilling Water (Ueber die Schwelung voellig getrochneter Braunkohle). P. ROSIN and H. JUST. Braunkohle (Halle), 28: 41 & 42, October 12 and 19, 1929, pp. 893–897 and 915–924, 2 figs. Results of investigation prompted by recent complaint concerning pollution by waste waters from distillation plants; as there are no prospects of economically purifying distillation waters of coals with high water content, aim has been to reduce injurious effect by distillation of completely dried coal.

Water Softening Plant at the Peerless White Lime Co. R. W. SMITH. Rock Products, 33: 6, March 15, 19–30, pp. 63–65, 3 figs. Description of water-softening plant which has been functioning for some time at Peerless White Lime Co., Ste. Genevieve, Mo., has several interesting features; designed and constructed by company engineers, its operation is entirely automatic; efficient automatic operation giving steady supply of soft water for boilers and other uses; hardness reduced to minimum.

Locomotive Boiler Washing. E. J. H. SOUTH. Junior Inst. of Engrs. (Lond.), 40: part 2, November 1929, pp. 81–95, 5 figs. Paper contains description of locomotive boiler, water supply, feedwater heating, and method of washing out; illustrated description of hot-water boiler-washing system.

Locomotive Boiler Feed Water Supplies and Their Treatment. A. V. PATERSON. Commonwealth Engr. (Lond.), 17: 7, February 1, 1930, pp. 249–254, 2 figs. Report on work of Commonwealth Railways Department on Trans-Australian line; map showing locations of water supplies; chemical analysis of Trans-Australian railroad water supplies; features of standard water wagons and treatment plants.

The Toedt exidimeter (L'ossidiometro di Toedt). L. KOEHLER. Notiziario Tecnico di Aeronautica (Rome), 8: 12, December 1929, pp. 106–107, 1 fig. Description of simple apparatus for immediate and direct measurement of metallic corrosion, incrustation, and oxidizing strength of solutions from measurement of intensity of electric current. Translated from Chemiker-Zeitung, July 20, 1929.

Good Filtration Pays in Many Ways. Paper Trade Jl., 90: 2, January 9, 1930, pp. 44–52, 10 figs. Importance of satisfactory water supply for paper mills; various types of filters; various substances that can be used as coagulants; feedwater filtration.

Water Purification. J. W. BERRIMAN. Paper Mill, 52: 46 and 48, November 16 and 30, 1929, pp. 8, 10, 14, 31 and 14, 16 and 24. Following methods of water purification are described: sedimentation; coagulation and sedimenta-

tion; sand filtration through either (*a*) slow-sand filters without coagulant, or (*b*) rapid-sand filters using coagulant; these may be either of pressure type or gravity filters.

Multi-Stage Water Distillation. Indus. Chemist. (Lond), **6**: 61, February 1930, pp. 61–62, 2 figs. Explanation of Christ four-stage column distillation system; comparative calculation of thermophysical processes in respect to single and multi-stage distillation.

Modern Methods of Combating Water Scale, Rust, and Corrosion (Neuzeitliche Wasserstein, Rost- und Korrosions-bekaempfung). H. BALCKE. Gesundheits-Ingeniour (Munich), **52**: 52, December 28, 1929, pp. 881–884, 6 figs. Discussion of calcium-carbon dioxide equilibrium and its bearing on formation of rust and on corrosion of hot water pipes; outline of GROECK method of preventing corrosion and scale formation; laboratory tests and observations based on practice.

The Zeolite Process of Water Softening. Chem. Age, **21**: 544, November 30, 1929, pp. 502–503. Summary of existing knowledge.

(*References from "Chemical Abstracts" contributed by* DR. A. M. BUSWELL)

Apparatus for Deaërating Boiler-Feed Water by Spraying it in a Vacuum Chamber. Weir, G. & J., Ltd., and SIM, J. Brit. 306, 257, January 21, 1928. Chemical Abstracts, **23**: 20, 4989, October 20, 1929.

Boiler Crust Preventing. FELDMAN, EDWARD D. Fr. 664,039, November 16, 1928. Chemical Abstracts, **24**: 4, 909, February 20, 1930. Crust on boilers is prevented by the use of sulfonated vegetable or animal oils saturated with alkalies, the oils being submitted to a preliminary treatment at a high temp. and pressure. Resins or soaps may be added to the oils.

Deaëration of Feed Water for Boilers. MCDERMET, J. R. Can. Eng., **57**: 1291–2, 1929. Chemical Abstracts, **24**: 1, 180, 1930. The elimination of corrosion due to dissolved gases is accomplished either by deaëration or by deactivation. Deaëration removes all atmospheric gases. The value of H-ion determination as a measure of corrosive properties is stressed. Waters treated by the zeolite process offer greater difficulties in deaëration than lime- soda-process-treated waters.

Deaëration for Feed Water, etc. Atlas-Werke A.-G. (S. VON LE JUGE, inventor.) Ger. 483,213, December 14, 1928. Chemical Abstracts, **24**: 2, 451, 1930. Addition to 416,499.

Device for Supplying Mucilaginous Substances to Steam Boilers to Prevent Incrustation. KOBSEFF, JOAKIME. U. S. 1,739,640, December 17. Chemical Abstracts, **24**: 4, 909, February 20, 1930. Structural features.

Distilling Boiler-Feed Water. Naamlooze Vennootschap Neckar Watereiniger Maatschappij and H. NOORDENDORP. Brit. 301,666, January 10, 1928. Chemical Abstracts, 23: 17, 4290, September 10, 1929. Steam obtained by expanding the sludgy water from a boiler is used to evaporate the make-up feed water for the boiler. An arrangement of apparatus is described.

Heat-Exchange Device Suitable for Heating Boiler Feed Water. HENSZEY, ROY O. U. S. 1,740,300, December 17. Chemical Abstracts, 24: 4, 909, February 20, 1930. Structural features.

Incrustation Preventive and Remover for Use in Boilers. OBERHOLTZER, JOHN H. (One-half to ROBERT C. MURPHY.) U. S. 1,720,565, July 9. Chemical Abstracts, 23: 17, 4290, September 10, 1929. Starch (0.5 to 5.0 pounds) is used with a solution of 1 to 5 pounds alkali metal hydroxide in 20 to 100 gallons water in which 0.5 to 5.0 bushels of decayed wood have been digested.

Preventing and Removing Incrustation in Boilers. FELDMAN, E. D. Brit. 311,550, May 7, 1928. Chemical Abstracts, 24: 4, 910, February 20, 1930. The boiler-feed water is mixed with an alkali metal soap of sulfonated fat or fatty oil which has been previously exposed to high temperature and pressure (suitably a Na soap of sulfated castor oil which has been heated to 150° under 3 atmospheres pressure and may be emulsified with a solution of resin soap or resin and mixed with ordinary soaps).

Purifying Boiler Feed Water. BAUER, MORITZ. U. S. 1,737,448, Nov. 26. Chemical Abstracts, 24: 3, 674, February 10, 1930. Boiler sludge is conducted to purifying apparatus through an interposed expansion chamber in which the sludge is freed from steam, so that boiling over of the sludge in the purifying apparatus is prevented. The steam liberated from the sludge is caused to fill the space above the liquid level in a closed reservoir in which purified feed water is received from the purifying apparatus and from which it is supplied to the boiler, so that the steam excludes atmospheric O from contact with the feed water in the reservoir. Various structural details are described.

Purifying Feed Water. BRUCHHAUS, E. Brit. 305,848, March 9, 1928. Chemical Abstracts, 23: 20, 4989, October 20, 1929. The water is preheated by steam and vapor from a second heater, treated with reagents, then heated up to steam temperature in the second heater with fresh steam, and filtered. An apparatus is described.

Removing Gases From Water Lowers Its Corrosive Effect. MCDERMET, J. B. Water Works Eng., 82: 1186, 1190, 1929. Chemical Abstracts, 24: 1, 180, 1930. Dissolved O and, to some extent, CO_2 are the only gases concerned in the control of corrosion. Deaëration removes all gases except CO_2. Deactivation removes only dissolved O. It has been found of maximum benefit in the case of heated water supplies to remove all the dissolved O and as much CO_2 as possible. Reducing the dissolved O content in cold water supplies to less than 0.5 cc. per liter appears adequate. Because of its apparent simplic-

ity, deactivation is used for treating small quantities of water; for large quantities it is prohibitive owing to slowness of the reaction between scrap metal and dissolved O. There is ordinarily no difficulty in producing water free from corrosiveness if lime or SiO_2 is not precipitated. The deactivating apparatus in the absence of coagulation delivers water having both ferrous and ferric compounds in solution. To control pH values, $MgCO_3$ calcined and partly sintered is used as a coagulant. A pH of 9.8 is satisfactory and no advantage is gained by increasing pH value above 10.5. The treatment becomes impracticable in waters having pH values much below 7.5, owing to time of contact necessary between water and the Mg coagulant. Deaëration is practicable for almost any quantity of water in a heated condition. The largest use has been in the preparation of boiler-feed water in steam power plants. In the majority of these the boiler feed supply is condensed steam from evaporators or surface condensers, i.e., commercial distilled water. While no guarantee of specific removal of $Ca(HCO_3)_2$ from natural waters can be given by manufacturers) standard commercial deaëration apparatus is expected to remove all the CO_2 and approximately 40 percent of the bicarbonate hardness where 50 p.p.m. are present. With increased $Ca(HCO_3)_2$ content, more bicarbonate is removed, but the percentage values decrease. Control of corrosion by deaëration is successful in waters softened either by the hot or by the cold lime-soda process. Zeolite-softened waters are more troublesome, perhaps because the process is usually applied to waters in which corrosion control is more difficult. Corrosion in such waters is prevented by making the pH value 9.5 or over after deaëration.

Silicic Acid in Boiler-Feed Water. BRAUNGARD, K. Wärme, 52: 277–80, 1929. Chemical Abstracts, 23: 20, 4986, October 20, 1929. General discussion.

Treating Boiler-Feed Water. SCHENITZA, PHILIPP. Gor. 478,450, January 30, 1925. Chemical Abstracts, 23: 17, 4290, September 10, 1929. A compound to be added to the water for preventing and removing incrustation comprises a resin, gum, borax, and waterglass, suitably in the relative proportions 60, 20, 10, and 10, respectively.

Treating Feed Water for Boilers, Condensers, etc. KENT, DONALD W. U. S. 1,725,925, August 27. Chemical Abstracts, 23: 20, 4989, October 20, 1929. The water is subjected to the action of a stream of gas such as H or N to replace O dissolved in the water with a gas inert in respect to formation of scale and containing H, and the stream of gas used is recirculated for treatment of additional supplies of water. O is removed from the circulating stream by combustion with H, and fresh supplies of gas are added to makeup for the loss by combustion and solution. An apparatus is described.

NEW BOOKS

A Bibliography of Metallic Corrosion. W. H. J. VERNON. With Introduction by H. C. H. CARPENTER. London: E. Arnold & Co. Ltd. 341 pp. 21s. Reviewed in Chemistry & Industry, 47: 1367, 1928. From Chem. Abst., 23: 1098, March 10, 1929.—*R. E. Thompson.*

Floods in the Valley of the Mississippi a National Calamity: What Should Be Done About It? J. P. KEMPER. New Orleans: National Flood Commission, 1014 Chartres St. Cloth: 5½ x 8½; pp. 225. Reviewed in Eng. News-Rec., 102: 647, April 18, 1929.—*R. E. Thompson.*

Sanitary Engineering Laboratory Manual. ROBERT B. VAN HORN. Seattle: Univ. of Washington Book Store. 22 pp. From Chem. Abst., 23: 1710, April 10, 1929.—*R. E. Thompson.*

British Floods and Droughts. C. E. P. BROOKS and J. GLASSPOLE. London: Ernest Benn, Ltd. Cloth; 5½ x 8½; 199 pp. 10s. Reviewed in Eng. News-Rec., 102: 645, April 18, 1929.—*R. E. Thompson.*

Handbook of Cast Iron Pipe for Water, etc. Chicago: Cast Iron Pipe Research Assoc. 336 pp.; $3. From Chem. Abst., 23: 1782, April 20, 1929.—*R. E. Thompson.*

Zinc and Its Corrosion Resistance. New York: Am. Zinc Inst. 82 pp. $1. Reviewed in Mining Met., 10: 103, 1929. From Chem. Abst., 23: 1860, April 20, 1929.—*R. E. Thompson.*

Applied Chemistry. Vol. I. Water, Detergents, Textiles, Fuels, Etc. KENNETH C. TINKLER and HELEN MASTERS. London: Crosby, Lockwood and Son. 2nd. edition, revised. 296 pp. 15s. From Chem. Abst., 23: 1970, April 20, 1929.—*R. E. Thompson.*

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Vom Wasser. (Papers Given before the Annual Convention of the German Water Chemists and Water Engineers Held in Breslau in May, 1929.) Berlin: Verlag Chimie, G. m.b.h., Berlin W 10. 7 x 10 inches; pp. 282. 20 marks in paper; 21 marks bound. Reviewed in Eng. News-Rec., 104: 336, February 20, 1930.—*R. E. Thompson.*

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The Purification of Swimming Bath Water. Revised and enlarged edition. London: The Paterson Engineering Co., Ltd. Reviewed in Chem. News, **139**: 120, 1929. From Chem. Abst., **23**: 4989, October 20, 1929.—*R. E. Thompson.*

Arc Welding, the New Age in Iron and Steel. Cleveland; Lincoln Electric Co. 160 pp. $1.50. Reviewed in Rock Products, **32**: 104, 1929. From Chem. Abst., **24**: 327, January 20, 1930.—*R. E. Thompson.*

Water Supply in Hot Countries. H. KELLER. Berlin, 1929. Verlag von Wilhelm Ernst u. Sohn. 16 Rmk. From Bull. Hyg., **4**: 10, 877, October, 1929. This work is a very complete treatise in small space. Although brief, it is thorough and free from unnecessary detail. In the 170 pages the author has dealt with population and water demand, rights to water, characteristics of a safe supply, precipitation and run-off, sources of water and its procurement, physical, chemical, and bacteriological examinations, and water purification, sterilization, storage, and distribution.—*Arthur P. Miller.*